POSTHARVEST BIOTECHNOLOGY of FRUITS

Volume II

D. K. Salunkhe
B. B. Desai

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POSTHARVEST BIOTECHNOLOGY OF FRUITS

Volume II

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PREFACE

Increasing the availability of food has become an ever more pressing problem, with the world population expanding at a faster rate than that of food production. The growth in world food production is thus losing momentum relative to population growth. Projections of the World Food and Nutrition Study indicate that food production must be increased by about 3 to 4%/year by the end of 20th century to meet the needs of annual population increases. Obviously, world food supplies will need to increase at more rapid rates in the future than they have in the past if all the people are to be fed adequately. This is the greatest challenge ever presented to agricultural scientists and food technologists.

The present plateau of yields of the major food crops is a significant reversal. World hunger is widespread and growing. According to World Bank estimates, about three-fifths of the people in poor and less-developed countries do not meet their caloric and protein needs. The FAO figures state that about half a billion people in developing countries suffer from serious malnutrition and undernutrition. Thus, there is a great need to increase food supplies, especially protective foods such as fruits and vegetables which are valuable sources of essential nutrients, minerals, vitamins, and fiber.

A major and often neglected step toward offering a greater volume of nutritious food is to prevent its loss between the time of harvesting and consumption. It is estimated that due to defects and inadequacies in postharvest handling, transportation, storage, and marketing of food products, losses of more than 25 to 30% occur, especially in less-developed tropical and subtropical countries where there is an acute shortage of nutritious food. Such losses in respect to perishable products like fresh fruits and vegetables are of much higher magnitude. According to a report published by the National Research Council of the National Academy of Sciences, Washington, D.C., 1978, postharvest losses of fruits, vegetables, and roots may be as high as 80 to 100%, in some instances. Owing to their high moisture content, fruits and vegetables give a shrivelled look and stale appearance, with a loss of even 10 to 15% in their fresh weight, lowering their market value and consumer acceptance considerably.

Supplies of fresh fruits and vegetables can be increased to the extent of their existing postharvest losses, with the application of adequate technology to prevent their deterioration after harvest. Recent developments in agriculture have contributed significantly to improving our total world food production and quality of food. New biotechnologies are being evolved to protect valuable food materials, leading to a major revolution in "engineering a new agriculture" in the developing countries.

Developments in technologies of pre-treatment of raw fruit and vegetable products include the following: improved methods of harvesting and handling; various dehydration techniques (sun drying, freeze and osmotic dehydration, accelerated freeze drying, liquid nitrogen and cryogenic freeze concentration, dehydrofreezing and dehydrocanning, and freeze leaching for quality improvement), refrigeration, pre-cooling and cold storages; controlled, modified and subatmospheric (hypobaric) storages; radurization (pasteurization with radiation); use of preharvest and postharvest application of different chemicals (fungicides, ethylene absorbents, antitranspirants, wax-emulsions, antioxidants, in-package desiccants, senescence-retardants, antibiotics, and growth regulators); physical methods of food protection like use of new packaging materials and techniques; and processing of fruit and vegetable products into more stable products such as jams, jellies, preserves, juice, powders, purees, frozen disks or chunks, mixed beverages, baby foods, candies, tutti-fruitties, etc.

The main purpose of these volumes is to review and bring into focus the most significant scientific developments which have taken place in the area of postharvest biotechnology of loss reduction of fruits. The opportunity and potential impact of these newly developing biotechnologies to increase food supplies in such less-developed countries as India are enormous.

D. K. Salunkhe
B. B. Desai

THE AUTHORS

Professor D. K. Salunkhe, Vice-Chancellor, Mahatma Phule Agricultural University, Rahuri (Maharashtra) was a former Professor of Nutrition and Food Science at Utah State University, Logan, Utah (U.S.). Under his guidance, 80 postgraduate students received their M.S. or Ph.D. degrees. He has authored over 300 scientific papers, book-chapters, and reports. Some of his articles received recognition and awards as outstanding articles in biological journals.

He was an Alexander Humboldt Senior Fellow and a Guest Professor at the Technical University in Karlsruhe, West Germany. He was a Guest Lecturer at the Technological Institute, Moscow, USSR, and an exchange scientist to Czechoslovakia, Rumania, and Bulgaria on behalf of the National Academy of Sciences, National Research Council, as well as advisor to U.S. Army food research laboratories and many food storage, processing, and consumer organizations.

Professor Salunkhe was Sigma Xi President, Utah State University Chapter; Fellow of Utah Academy of Sciences, Arts and Letters; Fellow of the Institute of Food Technologists and Danforth Foundation Faculty Associate. He delivered the Utah State University's 50th Faculty Honor Lecture, "Food, Nutrition, and Health: Problems and Prospect", on the basis of his creative activities in research and graduate teaching.

Professor Salunkhe is presently a member of the editorial boards of the *Journal of Food Biochemistry, International Journal Qualitas Plantarum/Plant Food for Human Nutrition, Journal of Food Science, International Journal of Utilization Research,* and *Journal of Food Quality.*

He authored two textbooks: *Storage, Processing and Nutritional Quality of Fruits and Vegetables* (CRC Press, 1974) and *Post-Harvest Biology and Handling of Fruits and Vegetables,* with Professor Haard, (AVI Publishing Co., 1975).

In addition, Professor Salunkhe has recently coauthored the following books: *Guidelines for the Preparation of Theses and Dissertations,* D. K. Salunkhe, J. K. Chavan, and Urmilla D. Salunkhe, MPAU, Rahuri, 1982; *Preparation and Presentation of Scientific Publications,* D. K. Salunkhe and D. R. Bapat, MPAU, Rahuri, 1982; and *Preparation of Research Proposals for Financial Support,* D. K. Salunkhe and S. S. Kadam, MPAU, Rahuri, 1983.

Professor Salunkhe married Urmilla P. Shinde in 1955. They have two children: Kirti and Vishwas.

Dr. B. B. Desai is Associate Professor of Postharvest Technology, Mahatma Phule Agricultural University, Rahuri, India. He was born in India in 1941. He graduated with a B.Sc. (Agriculture) degree with honors from Poona University in 1963; during the same year he was appointed as a demonstrator in Agricultural Chemistry and promoted to lecturer's position in 1965. He has been an Associate Professor since 1973. He received his M.Sc. (Agriculture) and Ph.D. degrees from Mahatma Phule Agricultural University, Rahuri, and University of Agricultural Sciences, Bangalore, respectively. During his wide teaching and research experience, Dr. Desai has taught courses in organic chemistry, biochemistry, analytical chemistry, agricultural chemicals, food chemistry, biochemical techniques, and postharvest technology of fruits and vegetables to both undergraduate and graduate students.

Dr. Desai has authored over 35 scientific papers and reports in national and international journals, coauthored two books on agriculture in Marathi, and has contributed a half-dozen chapters in different books being published currently. He has guided 15 students for their master's degrees and is a major advisor for two Ph.D. students.

Dr. Desai married Vilasini A. Patil in 1966. They have three children: Varsha, Vikas, and Savita.

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Fruits—General Considerations
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Chapter 1

INTRODUCTION

The chief concern of the modern world is "enough and nutritious food for all". Mass starvation is hanging large over the heads of millions of people of the Third World, which has often been referred to as the world of hunger, poverty, ignorance, disease, and death. In most of the less-developed countries, food inadequacies relate not only to the quantity (caloric need), but also to the quality (nutrition). Such inadequacies lead to malnutrition as well as under-nutrition. The diets of many people of developing countries are generally low in calories and imbalanced in other essential nutrients, such as protein, vitamins, and minerals. The lack of variety in the diet, and particularly the acute shortage of protective foods such as fruits and vegetables, contributes significantly to the inadequate intake of the most needed nutrients. An inadequate amount of high-quality protein, vitamins, and minerals leads to the incidence of several specific and general diseases of man. While "beri-beri" persists as a serious illness prevalent in the rice-eating area of Asia, other deficiency diseases such as anemia, Kwashiorkor (a West African word meaning "red-haired body"), *Marasmus* (severe undernutrition), avitaminosis A, goiter, rickets, and pellagra are generally distributed throughout the developing world of Middle America, Africa, and most of Asia.

While the scientific and technological revolution has created unlimited opportunities for production of enough of the right type of food for all of mankind, enough attention has not been given to one of the vital aspects of the food problem, namely, *the conservation of food that is already produced.* As mntioned under the introductory remarks of Volume I, several research scientists and national government leaders throughout the world have become aware of the importance of *post-harvest conservation* of foods. According to a report published in 1978 by the National Academy of Sciences in Washington, D.C., entitled *Postharvest Food Losses in Developing Countries,* significant losses occur in perishable foods such as fruits, vegetables, roots, and tuber crops during their harvest, handling, storage, and distribution. It is, therefore, necessary to minimize these losses of foods by the application of available biotechnology and by undertaking new research in this vital area. The harvesting, handling, storage, processing, and distribution comprise a complex operation to ensure the conservation of foods. Coordinated efforts are essential to bring food and people into a reasonable balance. Borgstrom[1] proposed a strategy consisting of several action spheres to be harnessed, on a priority basis, as follows: (1) food production, (2) population control, (3) better storage and utilization of food and feed, (4) nutritional requirements, (5) disease control, and (6) resource appraisal (soil, water, and energy).

The postharvest spoilage of fruits is related to the botany, physiology, and biochemistry of their growth and development. Significant differences in storage behavior are noticed in the cultivars of fruit crops. The principal causes of deterioration include physical and mechanical damage leading to decay by microorganisms, especially the molds, and certain physiological disorders.

An account of postharvest biotechnology available to conserve the losses of major fruit crops, such as banana, citrus, mango, grape, apple, and other related fruits is presented in Volume I. Volume II covers the postharvest biotechnology of the less common fruit crops, namely: pineapple, papaya, avocado, guava, fig, passion fruit, sapota, and others.

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Chapter 2

PINEAPPLE

I. INTRODUCTION

Pineapple is one of the important fruit crops; it is widely distributed throughout the tropics from the equator to the east coasts of continents and on islands just inside the tropics (Hawaii, Taiwan). Since the pineapple adapts best to a mild tropical climate, west coasts are too cool for its growth.[28] It is consumed either fresh or in the processed form: juice, chunks, dice, and fruit salads. Alcohol and citric acid are other important products made from the pineapple. The pineapple is a delicious fruit with high vitamin (beta-carotene and ascorbic acid) and mineral content (principally K). Knight[20] predicted that the pineapple gives every indication of remaining an important world fruit crop in the near future.

The ''Spanish'', ''Queen'', ''Abalaxi'', ''Cayenne'', and ''Maipure'' are the important groups of pineapple cultivars. The cultivars have a vigorous growth habit, a short cycle, and resistance to diseases (especially mealybug wilt). Broad, short, and smooth leaves and cylindrical fruit are preferred characteristics in pineapple breeding. Other breeding aims include fruit color, flat eyes on a short but strong fruit stalk, a small ratio of leaf to fruit, firmness and color of flesh, content of fiber, dry matter, acidity, and vitamin C content.[13]

A. Botany

The pineapple (*Ananas comosus*) belongs to the family *Bromeliaceae*. It probably originated in Brazil (one species originated in Africa) from whence it moved to tropical America and Europe. In India and Malaysia, it has been cultivated since 1548.

Pineapple and related bromeliads live on the ground. It is a perennial, monocarpic herb and as in musa, each stem flowers only once and dies after fruiting; a side shoot then takes over. The leaves are long and narrow, arranged in a spiral on a short stem, forming a rosette. The flowers, 100 to 200 in number, are hermaphrodite, and seed setting takes place by cross-pollination.

The compound fruit is formed by fusion of the parthenocarpic fruitlets with the bracts and the central axis of the inflorescence. It takes about 5 to 6 months to ripen. On top of the fruit is a crown of leaves, which continues to grow until the fruit is mature, and may be used for propagation.[28] Likewise, the slips below the fruit can be used for propagation. Slips are really the crowns of small fruits, which are sometimes visible. The pineapple is best suited to a mild tropical climate with temperatures between 16° and 32°C. Frosts and freezing temperatures injure the plant; and very strong sunshine and dense shade are harmful.[20]

B. Cultivars

The pineapple cultivars are divided into four groups: (1) Cayenne, (2) Queen, (3) Spanish, (4) Abacaxi, and (5) Maipure.

Knight[20] and Samson[28] described the characteristics of pineapple cultivars. The most commonly grown predominant cultivar all over the world is ''Smooth Cayenne'' or ''Cayenne Lisse'' (in French), which belongs to the Cayenne group. It has several favorable characteristics such as spineless leaves, high production, high fruit quality, and resistance to gummosis. No other cultivar has fruit of such good and cylindrical shape ideal for canning. ''Smooth Cayenne'' is a very variable cultivar. Some other members of the Cayenne group are ''Hilo'' and ''Baronne de Rothschild'', the latter with spiny leaves. The well-known cultivars of the Queen group are ''Natal Queen'', ''Z Queen'', and ''Ripely Queen''. The ''Red Spanish'' cultivar also has spiny leaves and is rather variable. This cultivar is good

for fresh fruit export, but only fair for canning. "Singapore Spanish" has smooth leaves and is good for canning. Cultivars of the Abacaxi group (e.g. Pernambuco) have long spiny leaves and a very long fruit stalk. It is not suitable for canning or for export as fresh fruit.

C. Production and Distribution

The world production of pineapple during 1980 was 7,636,000 metric tonnes.[15] It has increased by more than 50% during the last decade. The U.S. (Hawaii) once produced more than half the world's pineapple crop. By the early 1960s, however, its share had dropped to less than one quarter; it now holds third place with about 8% of the world's total production. There has been a rapid increase in output in most pineapple-producing countries, especially in Thailand, Philippines, Mexico, Brazil, and the Ivory Coast (Table 1). The major producers of pineapple in 1980 were Thailand, China, U.S., Mexico, Philippines, and Brazil.

Recently the export of fresh pineapples to temperate countries has increased considerably. Smaller fruits in their early state of maturity are preferred for this purpose. Sixty percent of the fresh fruit is edible. Pineapple leaves yield a strong white fiber, from which silky cloth is made in the Philippines and Taiwan. Special cultivars are used for this purpose, grown at high density in shade. The fruits have to be removed, so it is not possible to combine fruit and fiber production.[28]

II. PHYSIOLOGY AND BIOCHEMISTRY

A. Development and Maturation

Pineapple has three distinct phases of growth: (1) the vegetative phase of leaf growth, (2) the generative phase of fruit growth, and (3) another vegetative phase of shoot growth. These three phases overlap to a certain extent, since leaf growth continues even after bloom has been induced, and stops only after the inflorescence has appeared, and shoot growth may start before the fruit is harvested.[28]

Pineapple, being native to the tropics, shows almost no photoperiodicity.[6] "Smooth Cayenne" is a short-day plant, and a succession of long dark periods induces bloom. Other pineapple cultivars react only weekly to day-length but may flower when the temperature falls.[4] The pineapple, being susceptible to frost, has its distribution limited from 25° North and South to 30° North (Assam) and 33° South (S. Africa). Overheated pineapple fruits suffer from "sun scald", and leaves and roots grow best at 32°C and 29°C, respectively. The growth of pineapple periodically ceases below 20°C and above 36°C.

The optimal temperature for fruit ripening in Guinea and Hawaii is about 25°C; at higher temperatures, the acid content of the fruit and its quality diminish. The best quality "Cayenne" fruits in Kenya are obtained at altitudes of 1400 to 1800 m.[24] The sugar-to-acid ratio of fruits at these altitudes is about 16, while it is about 38 at 1150 m. In pineapple, approximately 110 days are required to complete maturity and attain ripeness.

Pineapple generally needs a sunny climate, and reduction in light intensity is known to reduce its yield. Fruit color and malic acid content of fruit are also influenced by light. Pineapple is a true xerophytic crop and adapts to drought. Stomata are kept closed during hot hours of the day.

The natural process of flowering proceeds irregularly over an extended period, leading to peaks and valleys in production and export. It is therefore a common practice to induce bloom by the application of ethylene or other hormones. It is known that ethylene is the active principle responsible for flowering in pineapple. Acetylene, calcium carbide (acetylene-producing chemical), ethephon (under trade name Ethrel®) and beta-hydroxyethylhydrazine have been used to initiate flowering. True auxin-type hormones like NAA are also active and probably act by altering the hormonal balance in the pineapple stem.

Table 1
MAJOR PRODUCERS OF PINEAPPLE[a]

Country	1969-71	1978	1979	1980
Thailand	187	1400	1500	1500
China	804	873	888	888
U.S.	850	612	618	622
Philippines	251	465	605	600
Mexico	262	568	550	583
Brazil	437	575	572	572
Ivory Coast	127	312	315	320
World	4952	7125	7532	7636

[a] Times 1000 metric tonnes.

From Food and Agriculture Organization of the United Nations, Production Yearbook, Vol. 34, 1981.

B. Ripening and Senescence

The freshly harvested pineapple fruit contains 80 to 85% water, 12 to 15% sugars (of which two-thirds is sucrose and the rest glucose and fructose), 0.6% acid (of which 87% is citric and the rest malic acid), 0.4% protein, 0.5% ash (chiefly K), 0.1% fat, some fiber, and several vitamins (mainly A and C). The vitamin C content varies from 8 to 30 mg/100 g.

The range of chemical constituents of ripe pineapple (Smooth Cayenne) depending upon stage of fruit ripeness, and agronomic and environmental factors, is given in Table 2. The data indicate that cultural practices and climate greatly influence the fruit composition.[10]

The researchers at the Pineapple Research Institute of Hawaii proposed a biochemical basis for defining certain distinct phases in the development of pineapple fruit. Gortner et al.[17] monitored a series of physico-chemical changes taking place in the developing fruit, viz. respiration, chlorophyll, flesh pH, non-protein nitrogen, sugars, acidity, Brix, volatile esters, and fruit weight. During an approximately 110 day period of completion of flowering and start of ripening, significant changes in all these parameters take place. Based on changes in the chemical composition of pineapple fruit during the period from flowering to senescence, Gortner et al.[17] could distinguish the following five phases of fruit development:

1. Development — the period from the end of flowering to and including fruit ripening during which new tissue is formed and brought to morphological completion, and perfective chemical changes take place. It covers stages of pre-maturation and maturation, including ripening.

2. Pre-maturation — the period of fruit development after the completion of flowering up to 7 weeks prior to half-yellow shell, and a developmental period prior to the onset of maturation processes. It generally includes at least half the interval between blossoming and harvest, and is characterized by extensive cell enlargement.

3. Maturation — the period, about 6 to 7 weeks prior to half-yellow shell, during which the fruit emerges from the incomplete stage to attain a fullness of growth and a maximum edible quality. Most of the maturation processes must be completed while the fruit is still attached to the plant.

4. Ripening — the terminal 2- or 3-week period of first maturation during which the fruit develops fully and attains its maximum esthetic and edible quality. Most significant biochemical changes take place during this period. The ripening may occur either before or after fruit harvest; for some fruits the fruit must be detached for fruit ripening to proceed.

5. Senescence — the period following the ripening and development of the fruit during

Table 2
GENERAL ANALYSIS AND NUTRITIVE VALUE OF RIPE PINEAPPLE FRUIT FLESH

Constituents	Fresh Weight (%)
Brix	10.8—17.5
Sucrose	5.9—12.0
Glucose	1.0—3.2
Fructose	0.6—2.3
Cellulose	0.43—0.54
Pectin	0.06—0.16
Titratable acid (as citric acid)	0.6—1.62
Citric acid	0.32—1.22
Malic acid	0.1—0.47
Oxalic acid	0.005
Ash	0.30—0.42
Water	81.2—86.2
Fiber	0.30—0.61
Nitrogen	0.045—0.115
Ether extract	0.2
Pigments (ppm of carotene)	0.2—2.5
Carotene (mg %)	0.13—0.29
Xanthophyll 9 (mg %)	0.03
Esters (ppm)	0.2—2.5
Vitamins (μg/100 g fresh wt.)	
p-Aminobenzoic acid	17—22
Folic acid	2.5—4.8
Niacin	200—280
Pantothenic acid	75—163
Thiamin	69—125
Riboflavin	20—88
Vitamin-B6	10—140
Vitamin-A (as alcohol)	0.02—0.04
Ascorbic acid	10—25

From Dull, G. G., in *The Biochemistry of Fruits and Their Products*, Vol. 2, Hulme, A. C., Ed., Academic Press, N.Y., 1971, 303. With permission.

which growth has stopped and the biochemical processes of aging replace the perfective changes of ripening. The senescence may occur either before or after the fruit is harvested.

The pineapple maturation period is characterized by a rapid decline in shell and flesh pH, respiratory rate, and nonprotein nitrogen content of the flesh. The flesh Brix and titratable acidity increase markedly, and flesh carotenoid pigments level off. At the onset of ripening, there is an accelerated loss of shell chlorophyll; the flesh pH and rate of respiration begin to rise after attaining minimum values; the volatile esters accumulate rapidly, the non-protein nitrogen and sugars in the flesh and shell Brix begin to increase; while the flesh pigments increase rapidly, there is a decline in shell pigments; and titratable acidity begins to decline after reaching a peak (Figure 1).

Fruit enzymes have not been investigated thoroughly, although four pineapple enzyme systems, viz. bromelin, IAA oxidase, peroxidase and phosphatase have been studied, using pineapple plant stem as the source material. Gortner and Singleton[18] reported presence of

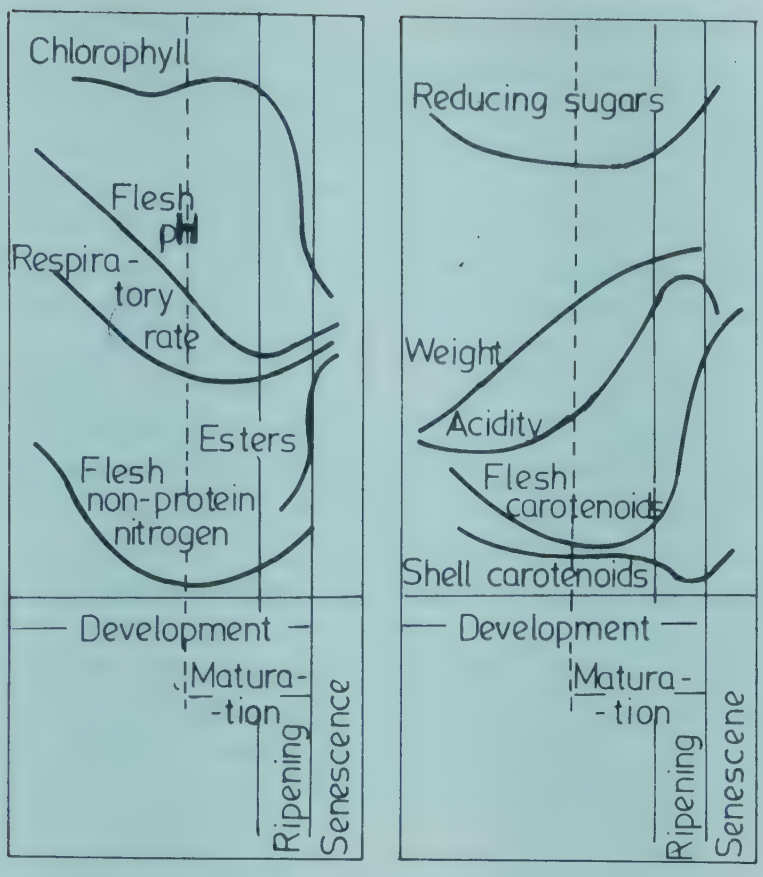

FIGURE 1. Physicochemical changes in the pineapple during development. (From Gorter, W. A., Dull, G. G., and Krauss, B. H., *HortScience*, 2, 141, 1967. With permission.)

peroxidase activity in the ripe fruit. Polygalacturonase activity in fresh fruit has also been detected.[19]

Biale[3] placed pineapple into a nonclimacteric category which is still a matter for dispute. Dull et al.[11] reinvestigated the pattern of respiration in fruit picked at six stages and subsequently stored. These investigators concluded that pineapple is not of the climacteric type, but it seems that there are strong grounds for suggesting that a climacteric occurs during the ripening of fruit on the tree.[26]

III. POSTHARVEST LOSSES

A. Extent of Losses

The reports of postharvest losses of pineapple, either estimated or determined accurately, are scant. The average minimum loss reported for fruits is 21%; occasional instances indicate estimates of 40 to 50% and above.[22]

B. Causes of Loss

1. Physiological

The pineapple is subject to a wide variety of disorders. If pineapple fruits in the field are excessively heated by the sun on one side, they may suffer from sun-scald, which renders them useless. This occurs in ripening fruits on slopes exposed to the sun. A physiological malady called "endogenous brown spot" causes big losses in cooled pineapples. Chilling injury of pineapple is encountered as a major physiological disorder and is found to have relationship with decrease in pH and ascorbic acid content of the fruit.[10]

2. Diseases and Pests

Pineapples are attacked by fruit flies, but they do not survive in the fruit. Heart rot in

pineapple is caused by *Phytophthora cinnamomi* and *P. parasitica*; the latter is adapted to warmer regions. *Thielaviopsis paradoxa* causes rot of planting material and of fruits after harvest. Fruit gummosis occurs in "Red Spanish", but "Smooth Cayenne" is resistant. It seems to be caused by the feeding of a caterpillar. Mealybug wilt is the most widely distributed pineapple pest, and also one of the most damaging, particularly to "Smooth Cayenne".[6] Yellow spot is caused by a virus transmitted by thrips. Nematodes are extremely dangerous enemies of pineapples. Other minor pineapple pests are scales, mites, fruit flies, the moth *Castnia licus* (same as in the banana), and the butterfly, *Thecla basilides*.[28]

Marbled fruit, also known as black, brown, or bacterial fruit rot, causes serious losses in canning crops grown in warm areas such as Mexico and the Philippines, but occurs only sporadically in Hawaii. The affected fruit showed no external symptoms but exhibited irregular hardening and brown mottling internally.[27] The disease develops rapidly at ripening, but does not occur in fruit picked green. The causative agent is presumed to be bacterial in nature but has not been definitely established.[8]

Water blister has been found in all the major pineapple-producing countries and can be a serious problem. It is a wet, soft rot of pineapple fruit core and pulp tissue that assumes a characteristic bright yellow color and from which emanates a distinctive odor of ethyl acetate. Fruit, both green and ripe, are infected by *Ceratocystis paradoxa* through the butt of the core. *Pink disease* has been reported from Australia, Hawaii, and Philippines and is characterized by pink to brown internal discoloration of ripe to overripe fruit with no external symptoms.[8]

IV. LOSS REDUCTION BIOTECHNOLOGY

A. Harvesting, Handling, and Maturity

The point at which a fruit is considered ready for harvest depends on its ultimate destination: cannery, export, or local market. The local market is often supplied as a by-product of the export and cannery trades; fruits that are too big, too small, or otherwise unfit for the other outlets go to the local market. Fruits for the cannery are picked ripe, judged mainly by the color and sometimes also by the sound when the picker knocks on the fruit.[28] In most places harvesting is still largely a hand operation. Harvested fruits are trimmed (crowns removed, bases cleaned) and placed in wooden boxes, loaded on flat-bed lorries, and sent to the cannery. The work is mechanized on large plantations.

Fruit for export is picked in a half-ripe state. The maturity is judged on the basis of external color, but this depends on cultivar, fruit size, and weather. Generally, grade II (colored halfway) is exported. Internal color is also taken into account, flesh must be translucid when cut transversely at one-third of the height. A minimum of 12% of total soluble solids is required in Hawaii.[2]

On the Ivory Coast, fresh pineapple fruit is graded in four classes: D(700 to 900 g), C(900 to 1100 g), B(1100 to 1500 g) and A(1500 to 1800 g). The fruit is packed in boxes holding 3×2 of the biggest to 5×4 of the smallest fruits and shipped in holds kept at 8°C.[28]

The problem with fresh pineapple is not how to store the fruit so that it can be ripened for use by the consumer, but rather how best to store the fruit in order to minimize loss of the quality in the fruit at the time of harvest.

B. Low-Temperature Storage

As in the case of many fruits and vegetables, refrigeration aids shipping and extends storage life of pineapples. One fruit, 'Smooth Cayenne', at the half-ripe stage can be held for about 2 weeks at 7.5 to 12.5°C, having an additional 1 week of shelf life. Mature green fruit (fruit picked with no yellow color showing on the shell) is susceptible to chill injury when stored at temperatures less than 10°C.[25,34] Py[25] recommended a storage temperature of 8.5°C for South African pineapple.

Endogenous brown spot frequently occurs simultaneously with chill injury. This is not always the case, since storage at 8°C for 1 week, followed by 1 week at 21°C, frequently induces endogenous brown spot, but not chilling injury.[10] About 1 week additional storage life of pineapples can be gained for each 6°C decrease in storage temperature for fruit showing about 25% shell yellowing at harvest. According to Dull,[10] at 7°C, the maximum storage life was about 4 weeks. A practical method to control the endogenous brown spot of pineapple has been discovered; dry heat is applied at 35°C for 24 hr, either before or immediately after cooling.[2]

C. Controlled-Atmosphere (CA) Storage

The effects of different levels of carbon dioxide and oxygen on respiration and storage behavior of pineapples have been reported. Stage 4 fruit were placed in atmospheres containing 21 (air), 10, 5 and 2.5% oxygen. Nitrogen made up the balance of the atmosphere. The respiration rate decreased with decrease in oxygen concentration of the atmosphere. When stage 4 fruit was placed in an atmosphere of 21% oxygen plus 0.03 (air), 5 and 10% carbon dioxide, the rate of respiration was suppressed slightly due to increase in concentration of carbon dioxide. Dull[10] concluded that decreased oxygen and increased carbon dioxide concentrations had no obvious effect on fruit quality. No major advantage of quality maintenance appears to be gained by manipulation of the concentration of these two environmental gases.

D. Chemical Control of Losses

1. Growth Regulators

A postharvest dip of half-ripe "Smooth Cayenne" fruit in a 100 ppm solution of 2,4,5-trichlorophenoxyacetic acid extended the shelf life from 6 to 14 days when the fruit was stored at ambient temperatures.[16] The quality of the treated fruit at the end of the 14th day of the period was judged to be good, while the control was fair to poor. Based on quality indices such as sugar, acid, pigment, and flavor, Gortner[16] concluded that the hormone functioned as a senescence inhibitor. Mature green 'Kew' pineapples treated with 500 ppm of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) extended the shelf life of fruit by 12 to 30 days at 21°C. Single applications of NAA solutions (50 to 200 ppm) increased flowering percentage, fruit size and weight, and prolonged time from flower differentiation to ripening by about 15 days.[9]

2. Other Chemicals

The postharvest fruit rot of pineapple caused by *Thielaviposis paradoxa* can be prevented by dipping the pineapple stalk in benzoic acid or Shirlan®. A fungicide more promising than Shirlan is imazalil. The infection by *Ceratocystis paradoxa* can be controlled by application of 1% sodium salicylanilide within 5 hr of cutting to the cut surface of the stem piece left on the fruit. Dowicide A ® is used commercially in Hawaii, but benomyl (0.63 lb active ingredient/acre) gave an excellent control under experimental conditions.[8]

The postharvest storage life of pineapples could be extended up to 2 or 3 weeks at 11.1°C and 1 week at room temperature when the fruits were dipped in coating material, drained, and packed into well-ventilated plastic cartons.[12] The effect of type of surfactant, pH, and film-forming material were investigated. The treatment reduced the endogenous brown spotting of pineapples.

E. Irradiation

Preliminary studies on effect of gamma radiation on the shelf life of fresh pineapple, conducted at the Hawaii Agricultural Experiment Station, University of Hawaii, indicated that irradiation with 50 Krad dose extends the shelf life of pineapple, as judged by the delay

in degreening of the fruit,[29] without impairing the physical and chemical or organoleptic characteristics of the fruit.[21,30-33] An irradiation dose of 30 to 500 Krad was found to induce formation of cytotoxic substances in pineapples.[32] These substances, however, disappeared in fruit irradiated at 30 to 50 Krad after 8 days of storage at 17.8°C, but they persisted in fruit irradiated at 100 or 500 Krad. Upadhya et al.[31] reported that like untreated fruit, storage conditions of 7.2 to 12.8°C and about 90% RH are optimum for irradiated pineapples to extend their storage life. Pablo et al.[23] concluded that a low-dose irradiation may be a feasible method of extending shelf life of fresh pineapples, which can tolerate a dose of about 50 Krad.[5]

F. Processing of Pineapple

By far the greatest part of the world's pineapple production is canned. The slices are the most valuable product, followed by pineapple juice, chunks, and dice. Some other products are fruit salads, sugar syrup, alcohol, and citric acid.

Canning is the most common preservation method used for pineapple. Collins[7] provided an excellent description of a typical large-scale canning operation developed in Hawaii. In general, the fruit is sorted by size, shape, and freedom from major blemishes. The ends, shell, and core are removed, yielding a cylinder of flesh which is cut into the usual slices, chunks and smaller pieces. Flesh remaining on the trimmed shell and ends, as well as fragments from cutting operations are used for crushed pineapple and juice. Much juice is concentrated and frozen because flavor quality is higher than that of single-strength canned juice. Quantities of frozen flesh are also packaged.[14] Ginaca machines are used to remove shells ends and cores at a rate of 125 fruits/min. They are then sliced in 3 sizes: 4/4, 3/4, and 2/4 and manually packed in cans. Other processed products of pineapple are: Chunks, spears, cubes, crush, tidbits, juice, sugar-syrup, alcohol, and cattle feed.

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Chapter 3

PAPAYA

I. INTRODUCTION

Papaya is a native of tropical America, but has now spread all over the tropical world. Some of the popular names of this fruit in different countries are: papaw or pawpaw (England), mamao (Brazil), lechoso (Venzuela) and fruta bomba (in Cuba, where papaya is a term of abuse). It is a popular breakfast and dessert fruit.

A. Botany

Papaya *(Carica papaya)*, is a small unbranched soft-wooded tree, ''almost an herb'' with latex vessels in all parts.[22] Large, deeply lobed leaves have long petioles and stand in a spiral. The plant is usually dioecious, with either male or female flowers. However, hermaphrodite (bisexual) trees also occur.[60] The fruit is a large, fleshy, hollow berry weighing about 0.5 to 2 kg. It is cylindrical or pear shaped on hermaphrodite trees, and more round on female trees. The central cavity is surrounded by more than a thousand small seeds, but seedless fruits also occur.

The genus *Carica*, to which papaya belongs, has been included in the family *Passifloreae* or even in *Cucurbitaceae*, but is best considered a member of the small family *Caricaceae* or *Papayaceae*. The genus contains about 40 species; only three are of horticultural importance, viz., *Carica papaya, C. candamarcensis* (mountain papaya) and *C. monoica*. Only *C. papaya* is grown in India to some extent, but cultivation of *C. monoica* may prove of some value.[39]

B. Cultivars

According to Storey,[65] as quoted by Samson,[60] ''Solo'' of Hawaii, ''Hortus Gold'' of South Africa, ''Improved Petersen'' of Australia, and ''Betty'' of Florida are the cultivars of papaya where the type is retained by inbreeding. Several improved ''Solo'' lines have been developed, viz., ''Solo 5'', ''Solo 8'', ''Bush'', and ''Sunrise''. All are hermaphrodites with pear-shaped fruit weighing about 0.5 kg, and the latter two have red flesh. ''Hortus Gold'' is dioecious, has a golden color, remains firm and weighs about 1.5 to 2.0 kg (Malan). In India, ''Coorg Honey'' is one of the best bisexuals. ''Semanka'' in Indonesia has big, red-fleshed fruits; and ''Guinea Gold'' (bisexual), ''Sunnybank'', and ''Hybrid 5'' (dioecious) are the important cultivars of Queensland.

C. Production

The major producers of papaya are Mexico, Brazil, India, Peru, Venezuela, and the Philippines. The world production of papayas increased from 1186,000 metric tonnes (MT) in 1969 to 1971, to 1917,000 MT in 1980.[32] During 1980, Brazil (400,000 MT) and Mexico (309,000 MT) produced more papayas than India (265,000 MT), which was the leading producer of papayas until 1977. There is a sizable export of papayas to the U.S. from Hawaii and Latin American countries.

II. PHYSIOLOGY AND BIOCHEMISTRY

A. Growth and Development

Under optimum conditions, the growth and development of papaya proceed at a faster rate. Seeds germinate in two weeks; flowers and fruits are produced in the leaf axils after

a juvenile period. Fruits mature within about 4 to 6 months, depending on the climate. Sex in papaya is determined by three genetic factors: M_1 is dominant for maleness, M_2 is dominant for hermaphroditism and m is the recessive for femaleness. Each ovule or pollen is a haploid, carrying only one of these factors.[60]

Selvaraj et al.[61] harvested fruits of four papaya cultivars (Coorg Honey Dew, Pink Flesh Sweet, Sunrise, and Washington) at various stages of development and analyzed these for sugars, organic acids, amino acids, vitamins, and minerals. The moisture content varied from 87 to 94%; and carbohydrates, from 2 to 12%. Sucrose, glucose, and fructose formed 7 to 50%, 14 to 78%, and 13 to 50%, respectively, of the total sugars. The dry matter content increased from about 7% at 15 days after anthesis to 13% at harvest. During this time, there was a steady decline in alcohol-insoluble solids, starch, and several minerals, and an increase in total sugars. The total and non-volatile acidity and organic acids, citric, and malic acids, decreased to a minimum at the full-ripe stage. These investigators further identified 17 amino acids at different stages of growth of papaya fruits. The concentration of individual acids changed considerably from anthesis to ripening stage. The vitamin C content of ripe fruits and those at the 15-day old stage was similar. The vitamin A and protein contents increased at the color break stage. Ripe "Washington" fruits contained the highest amounts of vitamin A and C. The contents of K, P, and Ca were high in early growth stages, whereas the Fe content showed little change during the fruit development. The papaya fruits showed a characteristic respiration climacteric during ripening. Blakesley et al.[15] reported that organoleptic qualities, volatile profiles, and lipid content of papaya were highly dependent on the degree of fruit maturity.

B. Ripening and Senescence

The most significant biochemical change occurring in the ripening fruit is the appearance of sugars varying a great deal in kind and quantity according to the type of fruit, variety and climatic conditions.[8] The polysaccharides are metabolized into sugars. The starch was broken down and sugars increased gradually during the entire period of 11 months of development in the 'Solo' variety of papayas.[56] Highly significant correlation existed between total sugars and tests for flavor and sweetness. The water content of the fruit decreased not only due to transpiration, but also due to accumulation of carbohydrates and other compounds.[45]

In ripe papaya, the predominant sugar is sucrose (48.3%), followed by glucose (29.0%) and fructose (21%);[21] and a small amount of sedoheptulose.[55] Papaya-invertase (beta-fructofuranoside) which catalyzes the inversion of sucrose has also been demonstrated.[21] An increase in the total sugars of ripening papayas has been observed by several workers.[7,25]

In papayas, the sugar content is greater than the acidity, and therefore the sweetness predominates. During the ripening of papaya at room temperature (24° ± 1°C), titratable acidity increased, and later, when the fruit was overripe, it decreased.[7] Chan et al.[19] identified the following non-volatile organic acids: alpha-ketoglutaric, citric, malic, tartaric, ascorbic, and galacturonic. Of these, malate, alpha-ketoglutarate, citrate, and ascorbic acid represent 95% of the total sugars. The total sugars and acidity of papaya are comparable to those of some tropical fruits (Table 1). The papaya is not high in acidity compared to other fruits.

Another obvious change during ripening of papaya is the reduced firmness due to the softening caused by the hydrolytic change of protopectin to soluble pectins. The enzymatic demethylation and depolymerization of the protopectin forms low molecular weight polymers with less methoxyl groups, which are insufficient for maintaining the fruit firmness.[44] Two pectic enzymes, viz., polygalacturonase and pectin methyl esterase, play important roles in altering the composition of the material in the cell wall and the middle lemella. Arriola et al.[7] found that the total pectin content reached a maximum value within 2 days after the fruit appeared to be ripe; the water-soluble pectin increased with a corresponding decrease in the protopectin as the fruit ripened fully.

Table 1
TOTAL SUGARS AND ACIDITY OF SOME TROPICAL FRUITS

Fruits	Total sugars[a]	Total acidity[b]
Papaya *(Carica papaya)*	9.00	0.15
Mango *(Mangifera indica* var. Haden)	22.48	0.03
Guava *(Psidium guajava)*	4.58	0.53
Mamey *(Mammea americana)*	14.40	0.80
Pineapple *(Ananas comosus)*	16.98	—
Chico zapote *(Acras zapota)*	13.00	0.06
Carambola *(Averrhoa carambola)*	—	1.03
Curuba *(Passiflora mollissima)*	—	2.60
Yellow passion fruit *(Passiflora edulis* var. flavicarpa)	—	4.60

[a] % fresh weight as glucose.
[b] % fresh weight as citrate.

Data from deArriola, M. C., Calzada, J. F., Menchu, J. F., Rolz, C., and Garcia, R., *Proc. Trop. Reg. Am. Soc. Hortic. Sci.* (Spanish), 19, 97, 1975. With permission.

Table 2
ASCORBIC ACID CONTENT OF SOME TROPICAL FRUITS

Fruit	State of ripeness	Ascorbic acid[a]
Papaya	Immature	42.0
	Ripe	55.0
Pineapple	Immature	0.92
	Ripe	0.93
Mango	Immature	93.28
	Ripe	18.81
Passion fruit	Immature	28.28
	Ripe	11.45

[a] mg/100 g fresh weight.

(From deArriola, M. C., Calzada, J. F., Menchu, J. F., Rolz, C., and Garcia, R., *Proc. Trop. Reg. Am. Soc. Hortic. Sci.* (Spanish), 19, 97, 1975. With permission.)

The vitamin C content of the developing papaya fruit increased gradually, reaching the maximum value at ripeness (55 mg/100 g).[7,25,56] Arriola et al.[8] pointed out that this was an exception to what is generally found. Most fruits demonstrate decreasing levels of vitamin C during ripening as shown in Table 2.

A progressive increase in the carotene and xanthophyll pigments have been observed during the papaya ripening. Arriola et al.[7] reported that carotenes increased from 0.3 to 2.0 mg/100 g of flesh. Munsell et al.[53] found that the Guatemalan papayas contained 0.025 to 0.030 mg of niacin per 100 g of fruit. A range of 0.17 to 0.64 mg with an average value of 0.32 mg/100 g fresh papaya fruit was reported by Asenjo et al.[9]

The most abundant mineral in papayas is potassium found combined with various organic acids. The elemental composition of papaya flesh from Hawaii as reported by Awada and Suehisa[11] was: N, 0.12%; P, 0.01%; K, 0.21%; Ca, 0.03%; and Mg, 0.02%. The mineral composition of two samples of Guatemalan papaya (per 100 g flesh) was: N, 0.11 and 0.097 g; P, 11.8 and 15.5 mg; Ca, 18.3 and 17.5 mg; Fe, 0.25 and 0.42 mg; and ash, 0.46 and 0.57 mg.[53] Frederick and Nicols[36] showed that 100 g of papaya flesh contained 39 calories, 10 g carbohydrates, 1.1 g fat, 0.6 g protein, and 0.9 g crude fiber. The water and crude

fiber contents varied from 88.6 to 89.3% and 0.6 to 0.7 g, respectively.[53] More than one hundred volatile compounds constituting papaya flavor have been identified. Linalool was the major component (67.69 area %), followed by benzyl isothiocynate (13.11 area %).[53]

III. POSTHARVEST LOSSES

A. Extent of Losses

The postharvest losses of fresh papayas have been estimated to vary from 40 to 100% in different countries with varying climatic conditions.[54]

B. Causes of Losses

1. Mechanical and Physiological

A commonly encountered physiological disorder of several tropical fruits, namely the 'chilling injury', has been observed in papaya. The decline in quality due to chilling injury may be significant enough to cause complete rejection of the produce by the consumer.[59] Injuries such as inability to ripen normally, lack of color development in the flesh, persistence of the green color in the skin, abnormal loss of firmness, accumulation of water in the tissues, and increased susceptibility of the fruit to fungal attack may be encountered. Impairment of ripening, pitting of the skin, failure to hydrolyze sucrose to reducing sugars, and waterlogging of flesh have also been observed.[57]

2. Diseases and Pests

Numerous fungi cause disease on papaya. The fungus *Colletotrichum gloeosporoides* for instance, causes anthracnose, as a result of which fruits are spotted.[68] The most serious disease of papaya, however, is mosaic caused by a virus. Storey[66] stated that several areas in the West Indies had to abandon papaya growing because of this "curse of the industry". Mosaic is transmitted by aphids, whereas the bunchy top of papaya, caused by mycoplasma, is transmitted by a hopper.[2]

Cook[27] described several diseases of papaya namely bacterial leaf-spot *(P. carica-papayae Robbs)*, bacterial necrosis *(B. papayae*, Rant), mildews *(Oidium caricae*, Noack and *O. indicum*, Kamat), leaf spot *(Curvularia carica-papayae* and *Cercospora papayae*, Hansford) and root rot *(Phytophthora palmivora* and *P. cinnamomi)*. The extent of losses of papaya crop caused by these diseases and pests have not been studied extensively.

IV. LOSS REDUCTION BIOTECHNOLOGY

A. Harvesting, Handling, and Maturity

Fruit for local consumption is picked when the green color is halfway changed into yellow; for export it is necessary to pick sooner, after the blossom end has turned color.[60] The fruit is cut off with a thin-bladed knife and placed stem down in a box padded with paper or wood wool to prevent bruising. It may be necessary to treat fruit in the packing house with hot vapor of ethylene dibromide to kill fruit fly. The fruits are then sized, graded, packed, and shipped.

B. Cold Storage and Preservation

Papaya is mainly used as a dessert fruit, being eaten when fully ripe just as it is or with salt, pepper, sugar or lime juice. Seeds are also eaten by some for their sprightly flavor, or for their reputed medicinal values.[39] The unripe fruit is used as a vegetable.

Arriola et al.[8] described the results of several storage trials of papayas conducted by several workers under different conditions. 'Solo' papayas picked at 3-4 ripe stage according to color development can be stored for 21 days at 7°C.[49] Lesser ripe papayas stored at

temperatures below 20°C were subjected to chilling injury and loss in quality.[43] Abou-Aziz et al.[1] tested different temperatures for storing papayas and found that fruits did not ripen at 10°C or less temperature and that at 16°C, papayas could be stored successfully to maintain their characteristics. Temperatures between 13° and 16°C have been found to be adequate for storing papayas.[69]

Jones[42] also observed that "Solo" papayas were subjected to chilling injury when the fruit remained at 7°C for 5 days; the injury was not observed when the fruit was stored at 10°C. Several other investigators reported severe chilling injuries of papayas below 7°C.[46,67] Arriola et al.[7] recommended 12°C as the critical temperature for a period not greater than 2 weeks. Chilling injury developed at longer times or lower temperatures than 12°C.

C. Controlled-Atmosphere (CA) Storage

Controlled atmosphere has not turned out to be beneficial to lengthen the storage life of papaya.[64] CA can be used for storing papaya by keeping oxygen at 1%, but must be done along with hot water, low temperature storage, and fumigation with ethylene dibromide, the latter to control fruit fly.[4] Hatton and Reeder[38] tested different storage atmospheres at 21°C. The fruit maintained an acceptable quality for marketing and showed no significant differences in weight loss, external color, ripening time, and soluble solids content. Arriola et al.[8] concluded that use of modified atmospheres raised the cost and did not necessarily imply better quality fruit. In the storage of papaya, temperature is as important as the degree of development and ripeness at the time of harvest.

D. Subatmospheric Pressure Storage

Exposure of papayas to subatmospheric pressure (20 mm Hg, 10°C, and 90 to 98% relative humidity) for 18 to 21 days during shipment in hypobaric containers, inhibited both ripening and development of disease.[5] Fruits ripened normally after removal from hypobaric containers, although abnormal softening unrelated to disease occurred in 4 to 45% fruits of one packer. He further reported that the fruits held in hypobaric storage had 63% less peduncle infection, 55% less stem end rot, and 45% fewer fruit surface lesions than those stored in a refrigerated container at normal atmospheric pressure. The postharvest fungicide-wax application (2000 ppm TBZ and 2900 ppm benomyl in diluted carnuba wax) further decreased the disease incidence.

E. Chemical Control of Losses

The nature of papaya makes it necessary to treat the fruit to reduce fungal attack. The papaya has a very thin skin which permits invasion by microorganisms in any bruise or scratch that it suffers during transport.

Submersion of papayas in water at 47°C for 20 min, followed by cooling with water, then fumigation with ethylene dibromide at a dosage of 8 g/m^3 for 2 hr at a temperature not less than 21°C[3] was found to be very useful. This combined process controlled the papaya fly (*Toxotrypana curvicauda*) and provided the additional advantage of removing the latex produced by the fruit at the time of harvest.

For the control of anthracnose caused by the fungus, *Colletotrichum gloeosporoides* and the fruit rots by *Alternaria alternata*, *Rhizopus* sp., *Phytophthora* sp. *Botryodiploida theobromae*, *Chaetromium globossum*, and *Fusarium solani*, the wide spectrum fungicides such as thiabendazole-2,(4-thiazoyl)-benzimidazole have been used at a level of 1.29 g/ℓ. This fungicide is found to be more effective than benomyl (methyl-1(butylcarbamoyl)-2-benzimidazole carbamate), copper oxichloride, zineb (zinc ethylene-bis-dithiocarbamate), or mancozeb (manganese ethylene-bis-dithio carbamate), but showed very poor control of *Rhizopus* and *Phytophthora*.[68]

F. Irradiation

The fungal attack can be controlled by gamma radiation, which extends the storage life of papayas. The dose of radiation required to control fruit rot is so high that the fruit cannot tolerate it.[8] Therefore, irradiation has generally been used in combination with the hot water treatment. Moy et al.[51] irradiated "Solo" papayas with a dosage of 25 to 75 krad and found that fruit quality was improved as compared to the fruit that had been only fumigated. Fungal control was effective with a dosage of 25 krad. No change in the total content of carotene was observed, and the skin color developed normally. Nevertheless, the vitamin C content appeared to be affected. Jiravatana et al.[41] found that the dosages of 25, 50, and 75 krad delayed the normal ripening process by 7 days. Beyers et al.[13] studied the compositional changes in total sugar, protein, lipid, vitamins, and trace elements of two papaya cultivars, viz., "Papinos" and "Hortus Gold", either irradiated at the commercially recommended dose (0.75 k Gy) or unirradiated (control) fruits. The statistical analyses of the constituents of irradiated and nonirradiated fruit showed no difference between them (Table 3). Blakesley et al.[15] further demonstrated that there were no significant differences in irradiated and nonirradiated papayas in respect to their volatile components (85 papaya volatiles), amino acids, and fatty acids. Examination of the gas chromatographic profiles and peak ratios from integration data of samples at the same degree of ripeness showed similar patterns. They also found that free amino acid and total amino acid content of fruit pulp remained unchanged by irradiation. The fatty acid composition of papaya as shown in Table 4 remained unaltered by irradiation, with the exception of unstable linolenic acid.

Clarke[26] proposed that the disinfection of papayas offers the promise of opening up a new market in the U.S. for papayas from Hawaii. A dose of 75 krad is sufficient to control the Hawaiian fruit fly. In addition, this treatment has the additional advantage of extending the storage life of the fruit by delaying the ripening processes.

G. Processing

The marketability of tropical fruits can be improved by processing the fruit for secondary applications as an alternative to their dessert use.[31] Tropical fruits such as papaya are prepared in many different ways as processed goods including purees, nectars, juices, frozen disks or chunks, mixed beverages, powders, baby foods, jams and jellies, concentrates, and candied items. The skin separation and seed removal form the initial steps for the manufacture of most of these products, which are performed either mechanically or by the lye peeling method using hot caustic soda solutions of 10, 15, and 20% concentrations.[18] This is followed by water washing. Off-odors and off-flavors develop in purees prepared from papayas without previous treatment against enzymatic and microbial action. No changes in the flavor of papaya purees were detected when they were treated with sodium metabisulfite (2000 ppm as SO_2) and stored at 30°C during 18 months.[30] Desulfitation was carried out by oxidation with a 0.25% solution of H_2O_2.

Papaya puree can be marketed as such or it can be used as a raw material for other products. When marketed as puree, it is usually canned or frozen.[8] Purees prepared from Hawaiian varieties of papaya contained 11.5 to 13.5% total solids, 50 to 90 mg 100 g ascorbic acid, 3.5 to 3.9 mg/100 g carotenoids and 84 to 88% moisture.[16] To diminish gelling and enzyme action, inhibitory factors such as enzyme clarificants,[40] sucrose additives,[23] heat treatments,[10] and acidification and gum addition[52] have been used. The acidification of puree has the advantage of permitting a milder heat process.

Nectars and juices are prepared using papaya puree either alone or with other fruit juices or flavors to form exotic beverages.[12,16,24] The effects of storage time, type of container, temperature, and other conditions on chemical composition, odor, and flavor of papaya purees, nectars, and beverages have been studied.[17,58]

Frozen papaya products, either puree, slices, or chunks, present some processing problems

Table 3
EFFECTS OF GAMMA IRRADIATION ON PAPAYA COMPOSITION

Constituents	Cultivars: Papines Control (c)	Papines Irradiated[a] (y)	Papines y-c	Hortus Gold Control (c)	Hortus Gold Irradiated[a] (y)	Hortus Gold y-c
(g/100 g)						
Water	86.10	86.40	+ 0.30	87.85	87.50	− 0.35
Fat	0.11	0.07	− 0.04	0.07	0.07	0
Ash	0.44	0.46	+ 0.02	0.46	0.46	0
Acidity	0.08	0.09	+ 0.01	0.12	0.14	+ 0.02
Protein	0.68	0.66	− 0.02	0.52	0.57	+ 0.05
Starch	0.08	0.06	− 0.02	0.12	0.10	− 0.02
Sugar	7.58	7.55	− 0.03	5.52	5.90	+ 0.38
(IU/100 g)						
Carotene	4285	4460	+ 175	2819	3480	+ 661
(mg/100 g)						
Ascorbic acid	89.61	91.89	+ 2.28	68.96	72.63	+ 3.67
Riboflavin	0.031	0.034	+ 0.003	0.02	0.03	+ 0.01
Niacin	0.77	0.51	− 0.26	0.33	0.31	− 0.02
Thiamin	0.04	0.03	− 0.01	0.03	0.02	− 0.01
Calcium	34.75	36.03	+ 1.28	27.05	35.15	+ 8.10
Phosphorus	10.05	9.50	− 0.55	7.50	8.20	+ 0.70
Iron	0.18	0.21	+ 0.03	0.43	0.38	− 0.05
Sodium	2.31	2.09	− 0.22	5.81	6.52	+ 0.71
Potassium	40.52	37.34	− 3.18	105.10	95.00	− 10.10

[a] Irradiation dose = 0.75 k Gy.

From Beyers, M., Thomas, A. C., and Van Tonder, A. J., *J. Agric. Food Chem.*, 27(1), 37, 1979. (Copyright by American Chemical Society.) With permission.

Table 4
EFFECT OF GAMMA IRRADIATION ON THE FATTY ACID COMPOSITION OF PAPAYA

Fatty acid	Control	Irradiated (0.75 k Gy)
	g of fatty acid/100 g fatty acids	
Lauric	1.3	1.1
Myristic	8.3	7.6
Palmitic	27.2	27.5
Palmitoleic	18.6	17.8
Stearic	1.4	1.5
Oleic	13.0	13.2
Linoleic	3.2	3.1
Linolenic	18.8	21.5

From Blakesley, C. N., Loots, J. G., duPlessis, L. M., and deBruyn., G., *J. Agric. Food Chem.*, 27(1), 42, 1979. (Copyright by American Chemical Society.) With permission.

due to the unusually high amount of bound water (34 to 37% as compared to less than 10% for other fruits) in the papaya tissue. The bound water has a close affinity to structural elements and remains unfrozen until temperatures are below −20°C. Acidification and faster processing methods yield better quality products.[6]

Papaya purees can be concentrated to decrease packaging and transportation costs. Losses in ascorbic acid and carotenoids, however, occur during such concentrations.[20] The carotenoids are reduced from 15 to 9.8% as a result of the isomerization process. The changes in flavor quality are not significant.

Siddappa and Lal[62] patented a procedure for drying mixtures of papaya juices, previously concentrated, with sucrose and other additives. Drying of papaya slices[48] and chunks[63] can also be adopted. To avoid undesirable darkening associated with the dried products, freeze-drying is used with good results to reach moistures as low as 3% (dry basis) in the preparation of papaya powder. Less common products such as mixtures of stewed fruit with dried milk, baby foods, and jam have also been studied. Gonzalez et al.[37] described the extraction of proteins from papaya leaves. Dabhade and Khedkar[28] prepared "tutti-frutti candy" from raw bits of lanced papaya having 1% acid, 68° Brix, and 25.7% moisture. The optimum relative humidity for storing this tutti-frutti was found to be 51.0%, and mold growth was observed above 70% relative humidity within 8 days. Mehta and Tomar[50] standardized a procedure for dehydration of ripe papaya slices, steeping in 70° Brix syrup containing 1000 ppm SO_2, which gave the best product. The retention of carotenoids in the dehydrated slices was 50%. Beyers and Thomas[13] analyzed papayas, mangoes, and litchis processed by canning, freezing, and gamma irradiation for their ascorbic acid, carotene, and sugar contents (Table 5). Papayas frozen under nitrogen accounted for relatively low losses of nutrients of 42%, as compared to 86 to 88% for the other two fruits. The vitamin content was halved during the heat processing of papayas. These authors concluded that chemical changes due to irradiation were generally small, amounting to losses of between 0 and 15%. In comparison, changes due to freezing and heat processing were considerable (about 50 to 70%).

V. PAPAIN PRODUCTION AND UTILIZATION

A. Definition and Grading

Papain is the dried latex from the tropical fruit, *Carica papaya* L., containing a protein hydrolyzing enzyme which has a number of specific technological functions.

Various quality grades have appeared on the market from time to time. Up to the mid 1950s, when the trade was dominated by supplies from Sri Lanka, three grades were known: (1) fine white powder form prepared by a specific process, (2) white oven-dried in crumb form, and (3) dark sun-dried papain in crumb form. Up to about 1970, papain was commonly brought in two grades: (1) first or high grade oven-dried papain in powder or crumb form, usually creamy white in color, and (2) second or low grade sun-dried brown papain in crumb form. Since 1970, other grades of papain resulting from new processing techniques have arrived on the market. As a result, papain can now be reclassified into three groups:[34]

1. Crude papains — ranging from first grade white down to second grade brown,
2. Crude papain in flake or powder form — sometimes referred to as semirefined, and
3. Spray-dried crude papain of higher activity — in powder form, referred to as refined papain.

B. Characteristics and Functions

Papain is a hydrolyzing enzyme which breaks down proteins in aqueous solution; it is, therefore, a protease (or proteinase) or proteolytic enzyme. It is a fairly mild enzyme, highly suited to its chosen uses, and because of this specificity, it has no really close substitutes.

Table 5
INFLUENCE OF IRRADIATION, FREEZING, AND CANNING ON ASCORBIC ACID, CAROTENE, AND SUGARS OF SOME SUBTROPICAL FRUITS

		Percent of control (100%)		
Constituent	**Fruit**	**Fresh irradiated**	**Frozen**	**Exptly. canned**
Ascorbic acid	Mango	83—89	14—37	67
	Papaya	101—114	58—100[a]	45
	Litchi	83—94	12—42	63
Carotene	Mango	86—103	100	102
	Papaya	94—97	69—71	53
Total sugars	Mango	102—141	55—62	59
	Papaya	88—91	84	368
	Litchi	81—107	123	274

[a] Frozen under nitrogen.

From Beyers, M. and Thomas, A. C., *J. Agric. Food Chem.*, 27(1), 48, 1979. (Copyright by American Chemical Society.) With permission.

although bromelain extracted from pineapple and ficin from figs have comparable characteristics.

The usefulness of papain in industrial manufacture depends on its activity, and care must be taken in production, storage, and marketing to protect its activity. Papain, particularly in solution, is easily oxidized by exposure to air and is destroyed in aqueous solution by higher temperatures (above 70°C) or by sunlight. It is easily inhibited by contact with metals such as iron, copper, zinc, and many others.

C. Utilization of Papain

Papain is used as a technological tool or processing technique in the following areas:

1. Food and beverage preparation and animal feeds
2. Pharmaceutical applications, primitive and modern
3. Textile industries, and garment cleaning
4. Paper and adhesive manufacture
5. Medical applications
6. Sewage disposal
7. Research
8. Analytical chemistry
9. Other miscellaneous uses

For over 50 years, by far the greatest use of papain has been in the chillproofing of beer and to a lesser extent in meat tenderization. In all cases, papain competes with alternative technologies and/or alternative enzymes, chiefly the plant proteolytic enzymes bromelain and ficin, but also animal proteases such as rennin and trypsin and several microbial (bacterial or fungal) proteases. Papain is usually preferred where (1) its specific action is more suitable than other proteases, (2) it is lower in price than its competitors, and (3) it is cheaper and easier to operate than alternative technologies.

Flynn[34] stated that the usage of papain in the beer industry has shown a steady increase over the past years and that this trend is expected to continue over next 4 to 5 years, but thereafter a larger rate of increase is likely to occur. There is also a great potential for increased use of papain in the meat industry, particularly in the developing countries. Increasing quantities of papain are being used in the pharmaceutical industry and medicine, e.g., in treatment of hard tissues of the skin (wart removal, skin cleaning creams, treatment of scar tissues on wounds), treatment of diphtheria, dispepsia croup in cattle, gastric insufficiency and other veterinary uses such as deworming. Two dramatic recent applications of papain are (1) plastic surgery on cleft palates and (2) treatment of prolapsed spinal disks by the injection of chymo-papain. Both these applications are still at the experimental stage. The largest use of papain in the pharmaceutical industry appears to be in the preparation of vaccines.

Papain has long been used in tanneries for leather bating to achieve greater mobility and softness in hides and skins. Papain breaks down the collagen between connecting fibers (inter-fibrillary proteins). It plays additional roles in the bating material as an unhairing agent and as an ancillary to using caustic soda instead of lime, which can give rise to problems in subsequent leather drying and other processes. Papain is sometimes added to trypsin, fungal or bacterial preparations, and for special purposes, especially where extra softness is required, e.g., in producing extra-soft calf leathers for special orders or uses.

D. World Trade in Papain

The principal producers of crude papain at present are: Zaire, Tanzania, Uganda, and Sri Lanka; the chief source of the higher qualities of flake papain and soluble, sterile, spray-dried papain is Zaire. Small quantities have come in recent years from Taiwan, Ecuador, and Tanzania. Other sources of small quantities of crude papain are: Kenya, Caribbean, Israel, Philippines, India, and Cameroon.

The main features in the pattern of papain production, which is changing in recent years, have been decline of Sri Lanka as a major exporter resulting from the outbreak of mosaic disease, followed by the decline of Uganda resulting from the expulsion of the Asian population; and paralleled with these, the development of the industry in Zaire, which is the principal producer of papain in terms of crude papain equivalent. The principal importing countries are: U.S., Japan, U.K., Belgium, and France. Almost all of the best quality papain finds its way eventually to the U.S., where it is refined and formulated into papain preparations which include other additives such as stabilizers.[34]

E. Quality of Papain

The effectiveness or potency of papain is most usefully expressed in terms of its "activity", which is a measure of its power as a catalyst. This is expressed in units of activity defined in terms of the weight of substrate (reactant) transformed or product formed in a given time. Thus, one unit of activity of papain is the amount of enzyme catalyzing the hydrolysis of one mole of protein in one minute at specified conditions of pH and temperature (e.g. 30°C, pH, 5.0). Specific activity of the pure form of papain may be expressed in units of activity/mg of enzyme protein.

The deterioration in quality of crude papain has given cause for concern among the end-users. The first grade white papain with an enzyme activity of 500 units has become increasingly rare and is being replaced by No. 2 grade with enzyme activities around 300 units. Moreover, the old distinction of "No. 1 White" and "No. 2 Brown" no longer applies, and variations in quality are greater than ever before. The principal origins of poor quality papain are (1) faulty tapping and collecting, (2) faulty drying, (3) incorrect storage and packaging, and (4) the activities of some middlemen.

Lassoudiere[43] and Foyet[35] described the best tapping and collecting procedures, but poor

tapping and collecting still prevail despite the wide availability of information on the best techniques. The critical areas pointed out by these investigators are: (1) tapping by incisions which are too deep and allow juices and starch from the fruit pulp to contaminate the latex; (2) tapping at times other than in the morning or on overcast days which results in quality reduction of the latex, (3) tapping too soon before maturity or too long after maturity, and (4) collection of the coagulated latex clinging to the fruit. All these should be avoided, as should also the practice of leaving latex for too long in the sun, where it can lose enzyme activity and collect foreign matter such as insects and dust. Other factors such as variety, size of fruit, position of fruit on the tree, age of the tree, etc. can also contribute to papain quality.

Lack of drying equipment is the main cause of concern in drying the latex, especially in heavy rainfall areas. Sun drying leads to browning of the papain and to a considerable loss of enzyme activity, an important conservation aspect. The provision of oven-drying facilities, perhaps on a cooperative basis, would lead to an improvement in quality. Storage in poor environments by middlemen leads to deterioration in quality. Better packaging practices could reduce losses of papain quality during storage and transport. Flynn[34] recommended the following: (1) packing in agreed standard weights (50 kg), (2) use of new rather than second-hand sacks, (3) clear markings of content, grade, and origin, and (4) proper sealing of plastic bags. These practices would help greatly to get the trade on a better footing and would promote the interests especially of small farmers supplying crude papain, who have no capital equipment for the production of refined papain.

The crude "Brown No. 2" grade papain brings roughly $3.60 to $5.20 per kg and crude "White No. 1 grade" from $5.20 to $8.60 per kg. Prices for the flake and powder papains are less well known.

Papain is an economically important alternate product of papaya culture. The process of collecting and drying papain is simple, needing no elaborate equipment. The fruits grown for this purpose should be thinned so that each one hangs separately. The unripe fruits are lanced with a non-metallic or stainless steel knife and the latex is collected in glass or porcelain vessels. Four cuts on a fully grown mature fruit give better yields of papain, and more than five tappings deteriorates quality. The latex hardens in about 15 min and is then put in alcohol for precipitation, washed with acetone, and dried under vacuum over sulfuric acid at room temperature.[39] Sodium bisulfite added at the time of collection acts as a preservative and improves quality of the product.

The papaya cultivation and papain industry may prove to be profitable in India. Hayes[39] stated that this may depend on the profitable use of the scarred fruit. The quality of such fruits does not appear to be affected, but the appearance is less attractive with lowered consumer acceptability. The green fruits, whether scarred or not, contain about 10% pectin on a dry weight basis, and it may be possible to use them profitably for the production of pectin.[29]

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Chapter 4

AVOCADO

I. INTRODUCTION

Avocado is a nutritious fruit consumed primarily as a fresh product. Though typically a high fat fruit, the avocado also contains rare sugars of high carbon number and is relatively rich in certain vitamins, minerals and nitrogenous substances. It is a popular food of central America. It has a high oil content with a wide range (3 to 30%), and low sugar (about 1%); hence it is recommended as a high energy food for diabetics. Avocados are eaten on bread and tortillas or in salads with lemon juice, salt and pepper. They cannot be cooked. Avocado oil is in great demand for the preparation of cosmetics. It is pressed from fruit rejected for export. The seed is made into chicken feed.

A. Botany

Avocado *(Persea americana)* belongs to the family *Lauraceae*, together with laurel and cinnamon. Three ecological races (subspecies) are recognized: Mexican, Guatemalan, and West Indian, which may be regarded as subtropical, semitropical, and tropical, respectively. Many cultivars of commercial importance and hybrids of these three races are available. Avocados are grown in tropical and subtropical climates ranging from 40° South to 40° North latitude.

The physiological differences among the three races are important commercially and relate to maturity date, fruit size, peel texture, flavor, oil content, disease tolerance, storage characteristics, climate, and cold tolerance of the tree.[2] Mexican cultivars are well adapted to the cool climates of the tropics and subtropics and are the most cold tolerant of the three races. The West Indian cultivars are best adapted to the lowland tropical conditions of high temperature and humidity. The Guatemalan cultivars are intermediate between these two cultivars in respect to climatic adaptation. The Mexican cultivars produce a small type fruit (85 to 340 g) with thick skin which is usually smooth and glossy, while the Guatemalan fruit is large in size (340 to 560 g) with a relatively thick (1.6 mm) and coarsely granular skin. Fruits of the West Indian cultivars are intermediate in size, and the skin is generally smooth, pliable, and leathery in texture. Fruits of the Mexican race mature earlier than or simultaneously with the West Indian cultivars. The Guatemalan and its hybrids are the late-maturing cultivars.[29]

B. Cultivars

There are hundreds of avocado cultivars; many are hybrids of the races. The most popular avocado in the world is ''Fuerte'' which is a hybrid (group B) between Mexican and Guatemalan races. It has a pear-shaped fruit with a high oil content (up to 26%), horizontal branches, and a tendency to alternate bearing. 'Hass' is a Guatemalan (group A) self-fertile cultivar with medium-sized, round fruits that turn purple on ripening. Both are not well suited to the tropics. Florida cultivars (''Pollock'', ''Simmonds'', ''Booth 8'', ''Booth 7'', ''Lula'' and ''Choquette'') are better for that purpose.[34] In Peru, with its great range of climates from dry lowland to cool mountain, many cultivars are grown, e.g. ''Fuerte'' (800 to 1800 m) and ''Nabal'' (110 to 1500 m above sea level). Tango et al.[45] have given many particulars on size, oil, flesh content, etc. of Brazilian cultivars. Moreuil,[27] as quoted by Samson,[34] considers ''Collinson'' and ''Simpson'' to be the best in Ivoloina, Madagascar. Cultivars such as ''Gottifried'' and ''Pernod'' (Mexican), ''Benik'' (Guatemalan), ''Black Prince'', ''Simmonds'', and ''Waldin'' (West Indian), ''Fairchild'', ''Long'' (G × W),

"Johnson", "Semil 34", and "Semil 44" (Puerto Rico) are grown at sea level in the Ivory Coast.

C. Production

The world avocado production increased from 688,000 metric tonnes (MT) in 1961—65 to 1,416,000 MT during 1980.[14] The major producers of avocado are Mexico, Dominican Republic, Brazil, U.S., Peru, Venezuela, and Haiti. The production as well as the consumption of avocado is rising rapidly. The fruit is being imported in recent years into the Netherlands (Holland) from countries like Israel and South Africa.[34]

II. PHYSIOLOGY AND BIOCHEMISTRY

A. Growth and Maturation

Avocados tend to continue to grow while attached to the tree and differences in size between avocado varieties is determined more by cell division than cell enlargement.[8] The respiratory pattern of avocado is similar at all stages of development; however, as the fruit matures and develops, the climacteric maximum appears earlier.[50] A significant feature of the climacteric pattern of respiration in all varieties of avocado is the decline following harvesting and the rapid rise to peak values of about the same magnitude, with the lag period (the time between harvest and the onset of the rise) varying from about 7 to 13 days in different varieties. This is not a specific varietal characteristic but rather a reflection of the state of maturity. Since avocados can be stored on the tree, considerable variations in the state of maturity at the time of harvest are encountered.[8] The biosynthetic capacity persists throughout maturation.

B. Ripening and Senescence

The avocado is a climacteric fruit, and its ripening is associated with an increase in respiration, referred to as the climacteric rise.[4] The respiration pattern is divided into three stages, the preclimacteric minimum, a period of low respiration; the climacteric maximum, a period when respiration is at its maximum; and the postclimacteric stage, indicating a decline in respiration (Figure 1). The ripening of the avocado is initiated most probably by endogenously produced ethylene.[11,26] Biale[6] showed that with the Fuerte cultivar, 10 ppm ethylene is required to immediately initiate the rise in respiration. Maximum synthesis of ethylene during ripening ranges from 100 to 700 ppm.[1] Biale[7] suggested that in most cases, the changes unique to the ripening process occur during the sharp rise in respiration between the preclimacteric minimum and climacteric peak. Fruit softening is generally discernible 1 to 2 days, and edible ripeness 1 to 3 days following the climacteric rise.

The pulp of "Fuerte", "Tatui", and "Wagner" cultivars contain the high amounts of fatty substances (22.1 to 25.5% on a wet weight basis) compared to other cultivars grown in Sao Paulo, Brazil.[45] Ripening of the avocado results in an increased content of fatty substances and free fatty acids. Among the avocado cultivars examined, the iodine value and saponification number ranged from 76.5 to 99.7% and from 167.6 to 190.1%, respectively; the unsaponifiable matter ranged from 1.04 to 2.10%. Despite the high fat content of the mature avocado, however, evidence does not support the idea of lipid utilization as respiratory substrates during the course of the climacteric. Sugars disappear with ripening and so do insoluble pectin, but whether they are utilized as respiratory fuels is not known.[8]

The fatty acid composition of the lipids of avocado fruit and avocado oil differs greatly with cultivars, season, stage of ripening, anatomical region of the fruit and the geographical growth location. However, the major fatty acid is always oleic (Figure 2) followed by palmitic and linoleic acids.[17,21,45] The fatty acids present in trace amounts are myristic, stearic, linolenic, and arachidonic. Lipids of avocado seeds contain less oleic acid and more

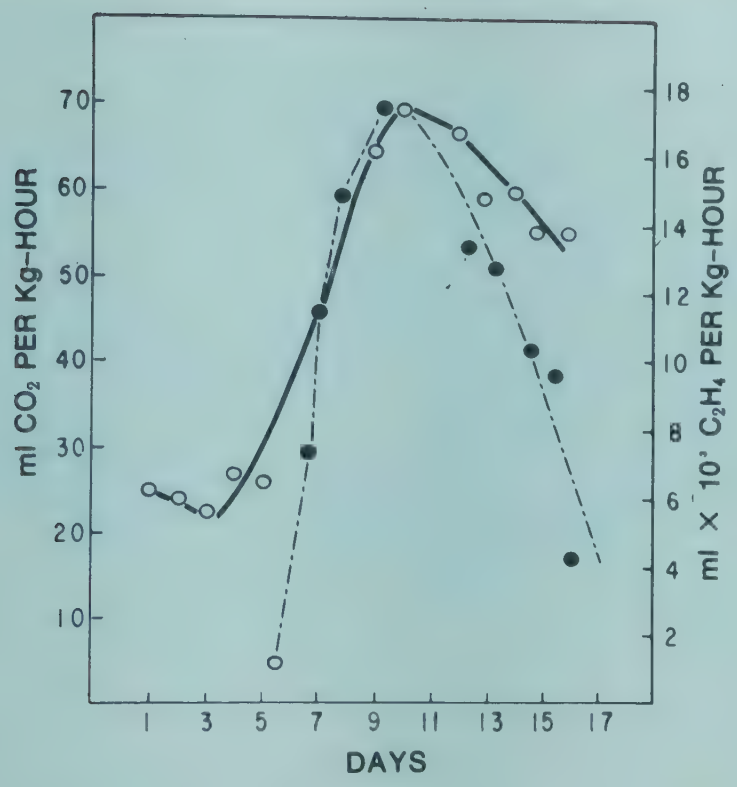

FIGURE 1. Fruit respiration and ethylene production by Fuerte avocado following harvest. (From Biale, J. B., Young, R. G., and Olmstead, A. J., *Plant Physiol.*, 29, 168, 1954. With permission.)

linoleic and linolenic acids than those present in avocado pericarp. The cuticular wax contains C_{20} to C_{27} long-chain fatty acids.[2,25]

Fuerte avocados contain higher amounts of free amino acids than other fruits; the major amino acids present are aspergine, aspartic acid, glutamine, and glutamic acid. The amino acids present in minor quantities are serine, threonine, alanine, valine, and cystine. The amount of total protein, carbohydrate, and ash content of avocado ranges from 1.21 to 2.26%; 1.82 to 7.80% and 1.0 to 1.4%, respectively, on a fresh weight basis.[18,35] Avocados are rich in vitamin B6 (3.9 to 6.1 μg/g pyridoxine) and contain lesser amounts of biotin, folic acid, thiamin, riboflavin, calciferol (vitamin D), alpha-tocopherol (vitamin E) and 2-methyl-1,4-naphthaquinone (vitamin K). The biochemical changes associated with avocado ripening have been studied extensively at the cellular and sub-cellular levels. It appears that independent but interlinked phosphorylative and nonphosphorylative pathways are operative at the cellular level.[8]

III. POSTHARVEST LOSSES

A. Estimation of Losses

Coursey[13] reported that the postharvest losses of avocado were estimated to be 43%.[28] The smooth-skinned varieties are more prone to physical injuries during handling and transport than the rough-skinned varieties.

B. Causes of Losses

1. Physical and Mechanical

Certain fungi have been known to infect avocado fruit through lenticels, injuries, and *Cercospora* spot or scab lesions and establish themselves as a latent infection. The fungi, however, are unable to penetrate healthy and uninjured fruit.

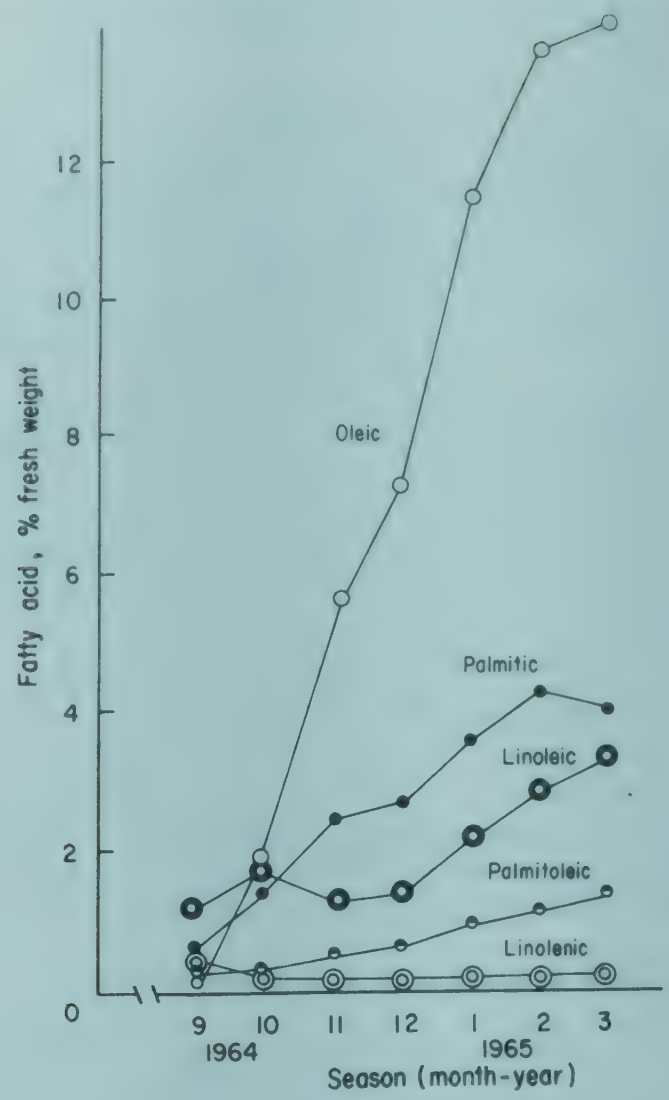

FIGURE 2. Seasonal changes of fatty acid composition in Fuerte avocado fruit. (From Kikuta, Y. and Erickson, L. C., *California Avocado Soc. Yearbook*, 52, 102, 1968. With permission.)

2. Diseases and Pests

The two most important postharvest decays of avocados are caused by the fungi *Colletotrichum gloeosporides* Penz, which causes anthracnose or black spot decay (Figure 3) and *Diplodia natalensis* Pole-Evans, *Phomopsis* sp. and *Dothorella* sp. which causes stem end rot.[2] The infection with *C. gloeosporides* occurs while the fruit is developing on the tree. All the cultivars grown in Florida are moderately susceptible to anthracnose, whereas the cultivars grown in California are even more susceptible to *C. gloeosporides*.[37] Stem-end rot occasionally results in heavy fruit losses. Immature fruits are more susceptible to this disease.

IV. LOSS REDUCTION BIOTECHNOLOGY

A. Harvesting, Handling, and Maturity

The avocado fruits are harvested manually with the aid of ladders, picking bags, telescopic poles filled with a cutting blade and catch bag, and hand clippers. The fruit is removed from the tree by either clipping or snapping the stem at the base of the fruit. Clipping and leaving a short stem is preferred since this reduces the chance of bruising and puncturing of adjacent fruit once they are placed in containers.[2]

In countries which have implemented maturity standards for avocados, the selection of

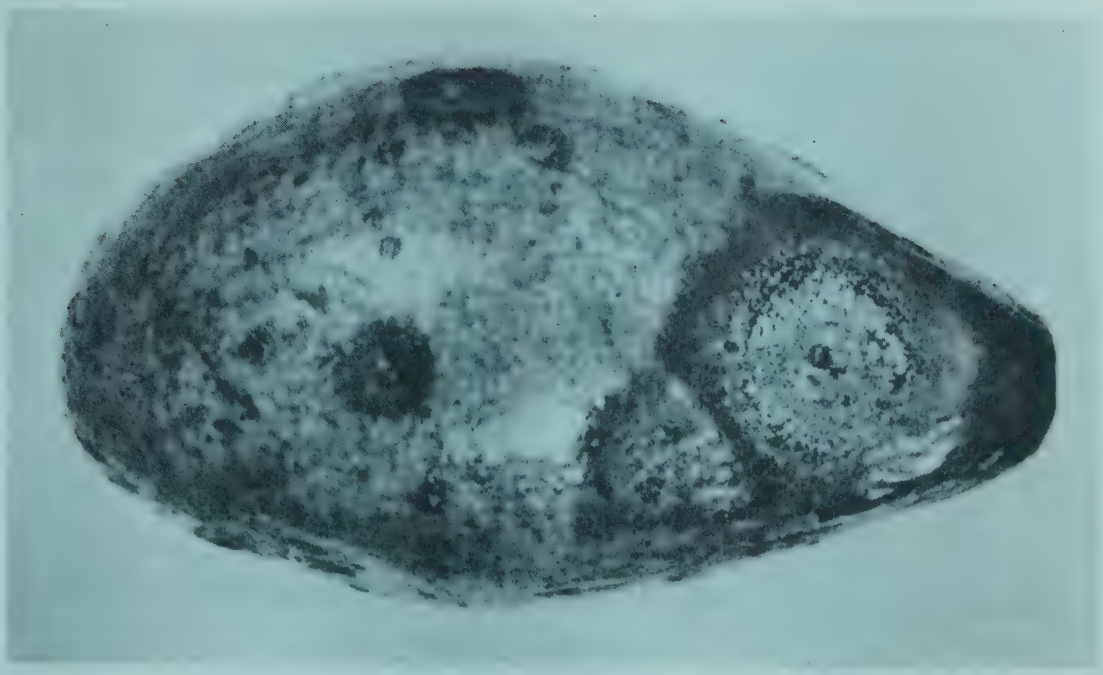

FIGURE 3. Anthracnose rot of avocado. (U.S. Dept. of Agriculture photo, in Ryall, A. L. and Pentzer, W. T.[31])

fruits to be harvested is generally based on weight and/or size. The California industry uses weight as a selection guide once the minimum oil content for maturity is reached. The Florida industry uses both weight and fruit diameter as selection criteria to harvest. Use of these parameters is very important since the harvest of avocados is often beset with the problem of variation in fruit maturity, especially early in the harvest season. It is also important that the fruit be shaded following harvest to prevent an increase in internal heat, and precooling is generally recommended to remove the field heat. Removal of excess heat prior to packaging reduces the refrigeration required during shipment to maintain the fruit at recommended temperatures and to provide a better control of the ripening process.

The modern packing house is completely automated except for the grading and packaging of the fruit, which are still done manually. Fungus-caused skin defects, harvesting cuts, and bruises are principal factors in grade reduction of the fruit. Fruit sizing is accomplished with either drop rollers (diameter) or weight sizers. The primary means of transporting avocados to the various markets are by trucks for shipments within the country and by ships for exporting purposes. Air freight is used occasionally. Transit time is an important factor since wholesalers need at least 1 to 2 weeks to market the fruit advantageously.[2]

Swarts[44] described a simple apparatus to measure the firmness of avocados. The firmness of fruits on the tree remained constant throughout the season, but that of picked fruits held at room temperature declined rapidly (indicating ripening). The ripening period was about 10 days less in avocado fruits picked later.

B. Low-Temperature Storage

Avocados can be stored for extended periods at 6°C. Certain varieties of avocado, however, develop characteristic chilling injury below 13°C (Figure 4). Hatton et al.[19] observed a graying-brown discoloration of the vascular system in addition to uneven ripening and development of off-flavors. In some instances, the fruit may appear satisfactory while in storage, but may subsequently develop chilling injury when ripened.[51] In general, cultivars of the Mexican race are of intermediate tolerance, and the West Indian cultivars are the least tolerant to low-temperature storage.[2] The recommended storage temperature for cultivars of the West Indian race is 12.8°C and for the Guatemalan and Mexican cultivars, 4° and 8°C, respectively.[19,24] Fuerte avocados can be stored best at 7.2°C (Figure 5).[52] The storage of

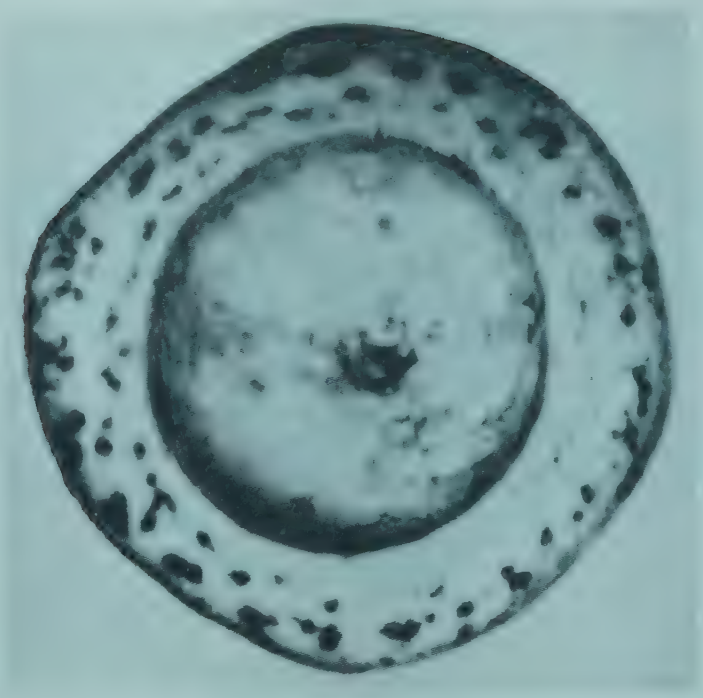

FIGURE 4. Chilling injury of avocado. (U.S. Dept. of Agriculture photo, in Ryall, A. L. and Pentzer, W. T.[31])

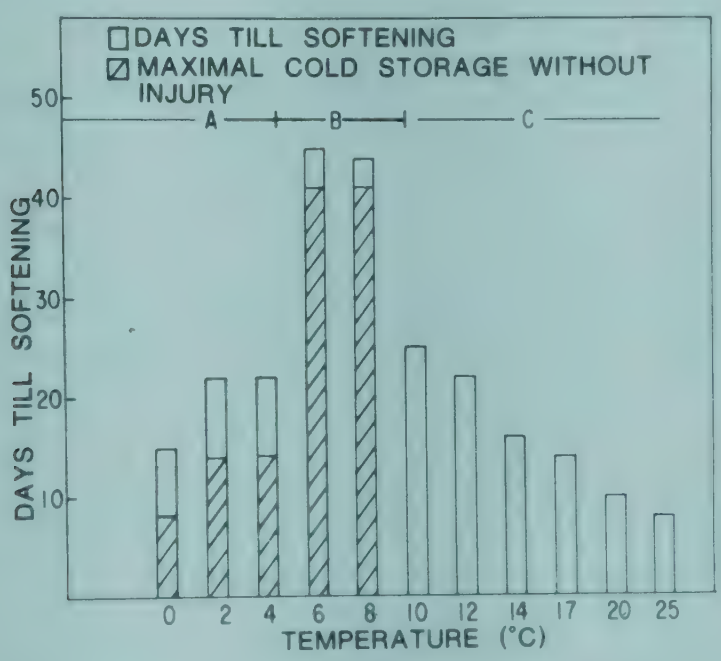

FIGURE 5. Effect of different storage temperatures on the softening time of Fuerte avocado fruit. (From Zaubermann, G., Schiffmann-Nadel, M., and Yanko, U., *HortScience*, 12, 353, 1977. With permission.)

low temperature-tolerant cultivars (Fuerte, Hass and Nabal) at 4°C is limited to about 2 to 4 weeks. The Hass and Nabal avocados are more resistant to chilling injuries than the Fuerte. Storage of avocados at low temperatures is important in retarding the development of postharvest decay, since no postharvest fungicides are used.[2] Lutz and Hardenburg[24] recommended a relative humidity of about 80 to 90% during the cold storage. Swarts[44] reported that avocado fruits kept at 5.5°C ripened slowly. The fruits picked toward the end of the season and held at 5.5°C for 30 days before holding at room temperature, ripened within 3 to 4 days.

Table 1
FRUIT QUALITY OF AVOCADOS AFTER STORAGE IN CA OR AIR

Storage time, temperature (°C)	Acceptable fruit		Softening time (days at 21°C)	
	Air[a]	CA[b]	Air[a]	CA[b]
Cultivar — Booth 8				
No storage	100	—	6.5	—
20 days				
4.5	80	93	4.8	5.8
10.0	33	60	1.6	5.2
40 days				
4.5	17	73	—	6.4
10.0	0	43	—	3.8
Cultivar — Lula				
No storage	100	—	6.4	—
20 days				
4.5	80	100	3.3	6.0
10.0	47	100	3.1	6.0
40 days				
4.5	0	100	—	5.1
10.0	0	100	—	5.4

[a] Air at 2.5°C.
[b] Controlled atmosphere of 2% O_2 and 10% CO_2.

From Spalding, D. H. and Reeder, W. F., *Proc. Fla. State Hortic. Soc.*, 85, 337, 1972. With permission.

C. Controlled-Atmosphere (CA) Storage

Several studies on use of controlled atmosphere (CA) to extend storage life of avocados have been reported. Early investigations with Fuerte avocados showed that within the range of 2.5 to 21.0% O_2 concentration, the time to reach the climacteric peak extends in proportion to the decrease in O_2 concentration.[5] Young et al.[49] demonstrated that the delay of the climacteric could also be achieved with 10% CO_2 and 21% O_2. The presence of low O_2 and high CO_2 (5 to 10%) tends to suppress the intensity of respiration.[49] In addition, the high CO_2 reduces the effectiveness of ethylene in stimulating the ripening process.[30] Use of 2% O_2 and 10% CO_2 at 7.2°C doubles the normal storage life of avocados (Lula, Booth 8, and Fuch) under refrigeration alone;[20,39,40] the maximum storage time for these cultivars was 6 to 8 weeks. Spalding[38] stated that the concentration of CO_2 must be kept below 15% to prevent injury.

With CA storage, low temperature can be used without causing the chilling injury.[41,47] The optimum temperature for CA storage varies with the cultivar, maximum storage time for any cultivar being 60 days.[39,42] These workers showed that the use of controlled atmosphere (2% O_2 plus 10% CO_2) at 7.2°C doubles the normal storage life of avocados under refrigeration alone. The maximum storage life for Booth 8 and Lula cultivars of avocados was about 6 to 8 weeks. Data reported in Table 1 show the beneficial effects of CA, especially at 4.5°C. Spalding and Reeder[41] reported that CA inhibits the softening process, and thus the fruit remains resistant to fungal invasion and development by *C. gloeosporides*. Ahmed and Barmore[2] stated that use of CA storage would be of primary importance in extending the marketing period of the late-maturing avocado cultivars.

Table 2
EFFECTS OF STORAGE TIME AND TEMPERATURE ON GAS COMPOSITION SURROUNDING AVOCADO FRUIT IN SEALED POLYETHYLENE BAGS

Storage time (days)	Gas concentration at each temperature (°C)[a]					
	CO_2 (%)		O_2 (%)		C_2H_4 (ppm)	
	20	30	20	30	20	30
4	7.6	7.5	4.2	6.2	0.1	1.6
6	8.0	8.1	4.9	2.4	0.3	1.1
8	7.7	6.5	4.3	2.4	12.7	2.3
11	8.9	6.6	4.1	2.9	6.7	0.4

[a] L.S.D. at 5% level for mean CO_2 values was 1.7. Significant differences between O_2 and C_2H_4 values were not detected.

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D. Subatmosphere Storage

In this system the commodity is maintained at a specific temperature in a sealed container at lower than atmospheric pressures. The unit is continually ventilated with moist air (80 to 100% RH) with a vacuum pump. Under subatmospheric pressures, the respiration of the commodity is reduced due to a reduced oxygen content. As a consequence of removal of ethylene and other gases produced by the commodity, the ripening and aging processes are retarded.[10,48,32,33] This system is essentially an aid to refrigeration and not its replacement.[38]

Apelbaum et al.[3] stored mature Hass avocados at 60 mm Hg for 70 days without adversely affecting ripening when transferred to atmospheric pressure and 14°C. Spalding and Reeder[42] and Spalding[38] reported that the optimum condition for low pressure storage of Florida avocados is 20 mm Hg and 4.5°C. Fruit thus stored remain firm for 3 weeks, and loss attributed to decay and chilling injury is minimal. Avocados stored at either 76 or 760 mm Hg had decreased firmness during the 3-week storage period and developed considerable chilling injury and decay. Studies reported on storage of avocados at subatmospheric pressure indicate that the storage life of avocados depends on the fruits' susceptibility to decay and chilling injury.[2]

E. Packaging of Avocados

Chaplin and Hawson[12] enclosed mature avocados in sealed polyethylene bags and stored them at ambient temperatures of different times (20 or 30°C for 4 to 11 days). Modified atmospheres developed inside the bags (Table 2 and 3), and fruit stayed firm and apparently nonripening, while they remained enclosed. The storage time and temperature did not influence the O_2 concentrations in bags, and the CO_2 concentrations differed only after 11 days of storage (Table 2). The ethylene concentration, however, varied considerably. The storage of avocados at ambient temperature either for 5 or 10 days did not alter the gas composition. The presence or absence of ethylene absorbent had no effect on O_2 and C_2H_4 levels, but the CO_2 level was significantly less in bags with absorbent blocks (Table 3). These investigators further observed that the total postharvest life of avocados was a function

Table 3
EFFECTS OF STORAGE TIME AND TREATMENT ON GAS COMPOSITION SURROUNDING AVOCADO FRUITS IN SEALED POLYETHYLENE BAGS

Storage treatment	Storage time (days)	Gas concentration		
		CO_2(%)	O_2(%)	C_2H_4(ppm)
Polyethylene bag	5	9.4	3.6	0.6
	10	9.2	5.9	0.5
Polyethylene bag plus ethylene absorbent[a]	5	1.9	3.9	0.5
	10	2.0	4.4	2.5

[a] Vermiculite/cement block (approximately 60 × 30 × 10 mm) impregnated with a saturated solution of $KMnO_4$.

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of storage time (Table 4). The extension of postharvest life achieved by storage of fruit in polyethylene bags during transportation could be expected to prevent losses resulting from premature softening.

F. Processing of Avocados

Although avocados are consumed principally as fresh fruit, certain mishappen, odd-sized, and imperfect fruit are not marketable as the fresh product and hence can be processed for the benefit of both growers and consumers.[2] Several attempts have been made to process such cull avocado fruits. Smith and Winter,[36] for example, reported that rapid freezing of Hass and Fuerte avocado slices by liquid freon, with proper treatment of the slices with ascorbic acid and malic acid produces a product comparable to fresh fruits. Sliced or pureed avocados can be frozen by liquid nitrogen to retain the texture and flavor for more than one year.[46] A freeze-dried avocado guacamole salad[15,16,23] can be stored in packed conditions up to 48 weeks at 18°C. An avocado salad base (guacamole) can be prepared by blending 100 parts of avocados with 5 parts of lemon juice, 4 parts chopped onion and 1 part salt.[43]

G. Storage of Avocados on the Tree

The avocado is unusual in that the fruit does not require picking as soon as it matures.[2] In California the Hass and Fuerte avocados can remain on the tree for six months or longer after maturity, while Florida-grown cultivars can remain on the tree for a period varying from 3 weeks to 3 months.[38] Generally, the fruits of the summer cultivars (West Indian race) remain attached to the tree for shorter periods of time as compared to the late maturing cultivars. Spalding,[38] however, did not recommend shipping of avocado fruits which have reached maximum maturity, because of reduced shelf life and internal seed sprouting. The length of postharvest storage life of avocados is primarily a function of cultivar, maturity, and temperature.

Table 4
EFFECTS OF STORAGE TIME AND TREATMENT ON THE TOTAL POSTHARVEST LIFE OF STORED AVOCADOS

Storage time (days)	Treatment	Total postharvest life (days)
5	Control	8
5	Polyethylene bag	11
5	Polyethylene bag plus $KMnO_4$	11
10	Control[a]	8
10	Polyethylene bag	16
10	Polyethylene bag plus $KMnO_4$	16

[a] Oversoft at first examination.

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Chapter 5

GUAVA

I. INTRODUCTION

Guava or guayaba is native of tropical America. It has spread to all tropical countries and is especially an important fruit crop of India. The fruit has a characteristic odor and is eaten fresh or cooked, but it is principally used for the preparation of jams, jellies, pastes and other similar products. It is rich in ascorbic acid and a fair source of beta-carotene, calcium, phosphorus, pantothenic acid, riboflavin, thiamin, and niacin.

A. Botany

Guava *(Psidium guajava* L.) is an important cultivated species of the *Myrtle* family. The crop tolerates a wide range of climates and altitudes up to 1,500 m, provided they are frost free. Samson[40] stated that the optimum rainfall and temperature for guava are from 1000 to 2000 mm and from 23° to 28°C, respectively. The crop is fairly salt and drought resistant, and soil pH may range from 4.5 to 8.2.[14] The fruit of the common guava has a rough yellow skin and is round, ovoid, or pyriform in shape. The cultivars ''Pyriferum'' (the pear-shaped) and ''Pomiferum'' (the round-shaped) represent two of the many variations that occur in guava; they are often referred to as pear and apple guavas, respectively. The fruit has many small hard seeds (153 to 664 per fruit) located in the center of the flesh. However, seedless (triploid) cultivars have been developed producing small amounts of misshapen fruit. The fruit color varies from white, deep pink to salmon red, and the flavor has been described as sweet, musky, and highly aromatic.[7,26,48]

B. Cultivars

Although a number of cultivar names are used, guava cultivars are not well established. The most popular in Uttar Pradesh (India) is ''Safeda'', a smooth skinned white-fleshed and sweet guava. Others grown in India are ''Seedless'', ''Chittidar'', ''Karela'', ''Sind'', ''Dholka'', ''Nasik'', ''Dharwar'', ''Habshi'', and ''Sardar'' (Lucknow 49). Cultivars grown in other tropical countries include ''Early red'', ''Madeira'', ''Madeira Hybrid'', ''Fran Retief'', ''Frank Malherbe'', ''Rousseau'', ''Red flesh'', ''Webber'', ''Blitch'', and ''Ruby × Supreme''.

''Branca'' is an improved sweet, white-fleshed cultivar grown commercially in the Sao Paulo state of Brazil. ''Arrons'', ''Hart'', ''Rolfs'', and ''Webber'' originated in California. ''Red Indian'' and ''White Indian'' (both from Florida) and ''Detwiler'' and ''Turnbull'' are presently grown in California. ''Blitch'' (oval-shaped fruit, about 5 cm in diameter and 112 g in weight) and ''Patillo'' (ovate to obovate in shape and 6.5 cm in length) are the two new guava cultivars which were developed at the Homestead Experiment Station, University of Florida. These are preferred for processing due to their high acid flesh. Two other acid-fleshed cultivars recommended for processing are ''Patillo'' and ''Pink Acid'' (both from Florida). ''Ka Hua Kula'' (''golden fruit'' in the Hawaiian language) is an acid-fleshed pink guava with a large size (207 to 277 g). ''Ka Hua Hua'' and ''Beaumont'' (about 235 g in weight), having good processing quality for guava puree, have been introduced from Hawaii.[22] ''Bassateen Edfina'' was introduced in Egypt during 1976; this gives a higher yield and better fruit quality than the parent stock ''Bassateen Elasabahia''.[38]

C. Production

The production of guava varies from about 2500 metric tonnes (MT) in Hawaii (United

States) to 200,000 (MT) in India. Other major producing countries are Mexico (about 127,000 MT), UAR (34,000 MT), Venezuela (17,000 MT) and some African countries producing about 3-4,000 MT per year.[4] Guavas have a good potential as commercial sources of pectin and oil from seeds.[48]

II. PHYSIOLOGY AND BIOCHEMISTRY

A. Growth and Development

Guava exhibits an unusual sigmoid growth curve. Fruits of "Safeda" guava increase rapidly in weight during the first 50 days of growth, more rapidly up to 100 days and very slowly during the last stages of maturity.[36] The fruit assumes a globose shape at maturity. The total and reducing sugars increase during growth;[44] these are mostly replaced by sucrose during the later stages of development. Titratable acidity also increases steadily in the beginning, and rapidly from fruit set to ripening. Pectins increase up to 110 days and then decrease.[24]

B. Ripening and Senescence

Ripening and senescence of guava are characterized by changes in carbohydrates, non-volatile organic acids, polyphenols, and volatile flavor constituents. The level of fructose increases during ripening and then decreases in the overripe fruit.[23] Seshadri and Vasistha[41] reported that glucose arabinose and maltose increased during ripening. Ogata et al.[30] found that unripe peel and pulp of guavas contained trace amounts of sedoheptulose, which increased to 0.04% in the ripe pulp. The decrease in astringency with guava ripening was associated with the increased polymerization of leucoanthocyanidins and hydrolysis of the astringent arabinose ester of hexahydrodiphenic acid.[28,49] Pectin content of guava increased during ripening and declined rapidly in overripe fruit.[25] Akamine and Goo[3] studied the respiration and ethylene production in fruits of four species and cultivars of guava, viz., *Psidium guajava* L., cultivar "Beaumont", *P. cattleianum*, cultivar "Sabine"; *P. cattleianum f. lucidum*, cultivar "Degener"; and *P. guajava* L., cultivar "Allahabad Safeda". The fruits of all cultivars were found to be climacteric in their respiratory behavior, with ethylene triggering the respiratory rise.

The average nutrient and proximate composition of guava is given in Table 1. According to Wilson,[48] although guavas are a rich source of ascorbic acid, their levels are subject to wide variation because of geographical location, horticultural practice, season, and cultivar. Reported values vary from 10 to 979 mg of ascorbic acid, per 100 g fruit. The skin and the outer flesh contain most of the ascorbic acid. The ascorbic acid content of guavas reaches a maximum in green, fully matured fruit and starts to decline rapidly as the fruit ripens.[1,15] These investigators also reported that the red-fleshed guavas had higher ascorbic acid content than the white-fleshed ones. The results of Palaniswamy and Shanmugavelu[33] indicated that the ascorbic acid of guavas varies greatly because of region and cultivar. Dedolph[12] reported a wide range of variation of ascorbic acid, from 11 to 1160 mg/100 g fruit in guava.

Guavas are a fair source of calcium, phosphorus and vitamin A (Table 1). French and Abbott[17] reported that the edible portion of pink-fleshed fruit had carotene content of 3.1 mg/100 g, while the white-fleshed fruit contained no measurable carotene (at 450 nm). These investigators also showed that about one-half of the color of the pink-fleshed fruit was due to lycopene. Asenjo and Muniz[5] reported that the edible portion of red fruit contained slightly more (0.17 mg/100 g) pantothenic acid than the white-fleshed fruit (0.13 mg/100 g). The thiamin content in five samples of wild guava varied from 0.038 to 0.080 mg/100 g with an average value of 0.059 mg/100 g.[6] Cordoba[11] found that the thiamin content of pink-fleshed guavas was higher (0.05 mg/100 g fruit) than that of the white-fleshed fruit (0.03 mg/100 g).

Table 1
THE AVERAGE NUTRIENT AND PROXIMATE COMPOSITION OF GUAVA FRUIT

Composition	Average	Composition	Average
Moisture[a]	83.3	Total pectin[a]	0.99
Dry matter[a]	16.6	Calcium[b]	17.00
Ash[a]	0.66	Phosphorus[b]	28.40
Crude fat[a]	0.36	Iron[b]	1.82
Crude protein[a]	1.06	Chlorophyll[b]	0.67
Crude fiber	3.80	Vitamin A (beta-carotene) (IU)	250
Reducing sugars[a]	4.00	Carotene[b]	0.69
Non-reducing sugars[a]	2.90	Xanthophyll[b]	0.13
Total sugars[a]	6.80	Ascorbic acid[b]	336.80
Total soluble solids[a]	12.00	Thiamin[b]	0.05
Sugar-acid ratio	10.10	Riboflavin[b]	0.03
Brix-acid ratio	17.40	Niacin[b]	1.18
Acidity (as citric acid)	0.80	Pantothenic acid[b]	0.13[c] (white pulp)
pH	4.7		0.17[d] (red pulp)
Alcohol-insoluble pectin[a]	0.75		
Pectic acid[a]	0.51		

[a] Percent.
[b] mg percent.
[c] white pulp.
[d] red pulp.

From Wilson, C. W., in *Tropical and Subtropical Fruits: Composition, Properties, and Uses*, Nagy, S. and Shaw, P. F., Eds., AVI Publishing, Westport, Conn. With permission.

The guava fruit contains about 74 to 87% moisture and 13 to 26% dry matter.[48] The winter crop had the highest content of chemical constituents and was of the highest nutrient quality, probably because of the lower temperatures involved.[35] Guavas contain 0.5 to 1.0% ash, 0.4 to 0.7% crude fat and 0.8 to 1.5% crude protein. The reported acidity and pH of guava flesh range from 0.33 to 0.99% and 4.7 to 5.4, respectively. Chan and Kwok[9] reported the total, reducing, and non-reducing sugars were present in amounts of 5.8, 5.5, and 0.3%, respectively, and the gas-chromatographically determined contents of fructose, D-glucose, and sucrose were 3.4, 2.8, and 0.3%, respectively. The sugar:acid ratio ranged from 4 to 25 and Brix acid ratio from 5 to 53, both being quite variable.[30]

Guavas are a fair source of pectin (Table 1). The values for total pectin range from 0.5 to 1.8%. The yield of pectin (about 11% on a dry weight basis) was larger than yields from citrus or passion fruit peel.[29]

Guavas possess a unique flavor that has not been completely characterized, although several compounds with a distinct guava aroma have been reported. Wilson,[48] summarized the research on guava flavor. Guavas contain 1.0 to 8.0% seeds, and the seeds contain 5 to 13% of an oil that is high in essential fatty acids, oleic acid being the main constituent.[46]

III. POSTHARVEST LOSSES (CAUSES)

The reports available to indicate the magnitude of quantitative and qualitative postharvest losses of guavas are meager.

A. Physical Injury

Blister-like lesions result from the feeding punctures of the capsid bug *Helopeltis antonii*.

Within a few hours following puncture of fruit, a brown and later black raised spot develops. The surfaces of such spots become blister-like, hard, and dry and sometimes crack. Extensive damage to young fruits may cause them to drop, but older fruits become deformed and cracked.[10]

B. Diseases and Pests

The most common postharvest disease of guava is anthracnose, caused by *Colletotrichum psidii*. Tandon and Singh[47] stated that it develops maximum at 35.0°C and 96% RH. The disease produces sunken spots on the fruit. Other diseases with similar symptoms, but which differ only in the color of accompanying pycnidia are fruit canker caused by *Pestalotia psidii* and Phoma-rot caused by *Phoma psidii*.[45] Soft watery-rot of guavas is produced by *Botryodiplodia theobromae* and *Rhizopus nigricans*. Infection by *Phomopsis psidii* starts at the stylar end as a circular water-soaked lesion. Injured fruits are very susceptible to *Macrophoma*-rot, caused by *M. allahabadensis*.[20] Sucrose gets totally hydrolyzed after infection, and marked changes also occur in the free and bound amino acids, amides, and organic acids.[13]

IV. LOSS REDUCTION BIOTECHNOLOGY

A. Harvesting, Handling, and Maturity

Guavas are hand-harvested in baskets 2 to 3 times weekly during an 8 to 10 week harvest season. Firm, yellow, fully mature fruits without insect or fungus damage are selected for harvesting and processed immediately. Mature guavas do not keep well and are usually transported rapidly to the processing plants. Guavas are generally shipped in small wooden boxes rather than orange crates because they are easily crushed or bruised; the damaged fruits deteriorate rapidly. Fully mature fruit should be refrigerated during shipment. Wilson[48] recommended that in the tropics, guavas should be shipped by barge at night to prevent spoilage. Daytime barge shipment should provide enough protection from excessive exposure to sunlight. Ideally, it would be best to ship firm, slightly underripe fruit and to finish ripening under controlled (refrigerated) conditions.

B. Low-Temperature Storage

Cold storage at 10.8°C effectively controls anthracnose disease of guavas. The green-ripe guavas can be stored in marketable condition at 8° to 10°C and 85 to 95% relative humidity for 2 to 5 weeks. Pantastico et al.[34] recommended a storage temperature of 8.3 to 10.0°C with 85 to 90% relative humidity for prolonging the shelf life of guavas up to 2 to 5 weeks. The loss in weight upon removal of guavas from such storage was about 14.0%.

C. Chemical Control of Losses

Spraying the trees with Bordeaux mixture (3:3:50), copper oxychloride, and cuprous oxide at weekly intervals was effective in reducing anthracnose.[47] Saha[39] reported that ripening of guavas was markedly hastened by treatment with growth chemicals such as 2,4-D and 2,4,5-T. The rate of repening doubled in guavas treated with 200 ppm 2,4,5-T. Singh et al.[43] found that dipping of guava fruits in calcium nitrate solution (0.5 to 2.0%) reduced weight loss, respiration rate, and disease occurrence, and maintained the edible quality of guavas for more than 6 days. The untreated fruits remained in an acceptable condition for only 3 days. Treatment with 10% calcium nitrate was found to be most beneficial in prolonging the storage life of guavas. Pre- and postharvest applications of morphactin (a chlorflurenol methyl ester) reduced postharvest weight loss, retained chlorophyll content, increased soluble sugars with both preharvest (2.5 ppm) and postharvest (2.5 and 5.0 ppm) applications, and extended the shelf life of guava fruits.[19]

Ahlawat et al.[2] harvested guavas when the color was changing from deep to light. These fruits were (a) waxed, or (b) $KMnO_4$ in muslin bags (at 10 g/kg fruit) was placed inside the storage polyethylene bag, or (c) potassium meta-bi-sulfite was applied as in (b). The latter treatment was found to reduce most of all losses during storage and gave an acceptable fruit quality. Wax emulsion (6%) retarded rate of guava ripening and extended storage life.[8]

D. Irradiation of Guavas

Effect of irradiation on postharvest behavior of guavas has not been studied extensively. The feasibility of irradiating guavas to delay ripening has been reported. Guavas irradiated at 30 krad and stored at ambient temperature exhibited a marked delay in ripening up to 3 to 5 days.[32]

E. Packaging

Khedkar et al.[21] reported that shelf life of guava fruits at room temperature can be extended if fruits are packed in 300 gauge polypack film bags. These fruits had less weight loss, more percentage of pulp and vitamin C, a high organoleptic score and no adverse changes in fruit. Bhullar and Farmahan[8] also found that guava fruits packed in 100-gauge perforated polythene bags prolonged their shelf life up to 5 days and minimized the physiological loss in weight. The titratable acidity and vitamin C content decreased during and with prolongation of the storage period.

F. Processing of Guavas

Guavas are processed commercially into jellies, jams, cheese, ketchup, puree, juice, powder, nectar, and clarified juice. Brazil's pack of processed guavas, 33,000 metric tonnes in 1972, has unofficially been estimated to be the world's largest. South Africa is reported to have produced in that year, packs of 6400 and 1036 metric tonnes for canned slices and nectar, respectively. Colombia produced 4742 metric tonnes of bite-sized crystallized fruit paste in the 1960s.[48]

Depending upon the purpose for which it is being utilized, the optimum maturity of raw material varies considerably. The degree of maturity of the produce for canning, for example, differs from that used for dehydration, for freezing or for making jams or preserves.[37] Most fruits used for canning are considered best when they are firm-ripe, full size and full of flavour, but are not ripe enough for table use. Rodriguez et al.[37] assessed the effect of stage of ripeness of fruit on the ''quality'' characteristics of canned guava. They found that full-ripe guava fruits gave a more acceptable processed product than firm-ripe fruit (Table 2).

Luh[25] prepared guava puree in the following manner: The washed guavas were processed at a constant rate through a paddle pulper fitted with 0.008 to 0.11 cm screens. To insure uniform color, the stone cells were removed by use of a paddle finisher fitted with 0.05 cm screen. The final product was deaerated, pasteurized for 60 sec at 90°C, and rapidly canned in either ''type N'' or ''type H''-enameled cans. The canned product was inverted, held for 3 min, and cooled with a water spray at 38° to 48°C. Guava puree is the basic starting material for products such as nectar and clarified juice.

Gauhar and Durrani[18] reported results of studies on the ascorbic acid retention of hand-peeled and lye-peeled guavas packed in (1) 40% sugar syrup, (2) 40% sugar syrup acidified with 0.5% citric acid, (3) guava juice adjusted to 40° Brix by addition of cane sugar and the original acidity increased by 0.5% with citric acid, and (4) guava juice with the original acidity increased 0.5% with citric acid. The canned guavas with higher acidity and Brix had greater ascorbic acid retention than other guava packs. The hand-peeled guavas retained more ascorbic acid than those peeled with lye.

Shah et al.[42] studied the storage stability of bottled guava juice at ambient temperatures. Single strength guava juice stored up to 270 days retained higher amounts of ascorbic acid

Table 2
QUALITY ASSESSMENT OF CANNED GUAVA OF DIFFERENT MATURITIES

	Characteristics of fresh fruit			Organoleptic acceptance of score of canned product[a]			
Ripeness stage	Pressure test (kg)	Volatile reducing substances (μeq/50g)	TSS (%)	Color, general appearance	Texture, mouth feel	Aroma	Taste
Quarter-ripe	12.53	341.6	11.92	4.92	4.42	4.50	4.25
Half-ripe	8.19	401.4	12.33	5.75	5.08	4.75	4.58
Eating-ripe	5.94	533.2	13.50	7.33	6.75	6.17	5.50
Full-ripe	3.45	812.7	13.17	7.50	8.33	8.25	7.25
Over-ripe	2.04	897.8	12.92	5.25	6.42	8.42	7.75

[a] Appraisal done twice, on separate dates, after 3 months storage at room temperature by 6 judges. Each factor was graded on a 10-point scale.

From Rodriguez, R., Agarwal, P. C., and Saha, N. K., *Indian Food Packer*, 25, 5, 1971. With permission.

(35%) than the guava juice with added sugar (25%). Fitting and Miller[16] examined frozen and unfrozen bottled guava juice stored up to 8 months. The bottled frozen juice had 90% retention of the original ascorbic acid, whereas the unfrozen juice retained 67% of its original ascorbic acid. The unfrozen bottled guava juice stored for 11 months retained up to 80 to 85% of the original ascorbic acid content after 12 months storage.[31]

Mehta and Tomar[27] reported studies on dehydration of guava fruits. These investigators standardized procedure for dehydration of guava slices, in 70° Brix syrup containing 1000 ppm SO_2, which gave the best product. The retention of ascorbic acid was only about 6%.

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Chapter 6

FIG

I. INTRODUCTION

The fig is one of the oldest known fruits to man, having been referred to in holy books such as the Bible. It is considered to be one of the first foods to be preserved by drying. The fruit is consumed fresh or in processed form.

A. Botany

The fig *(Ficus carica* L.) is believed to have originated in the Mediterranean basin.[11] It belongs to the *Moraceae* (mulberry) family having a synoconium (multiple accessory) type fruit, mainly a fleshy hollow receptable bearing numerous small flowers.[19] The fig needs a certain amount of chilling and can tolerate frost, down to −8°C and can be grown up to an altitude of 1200 m.[27] In the well known ''Smyrna'' fig, all flowers are female and have long pistils. Pollination is brought about by a wasp living in the caprifig, so that ''Smyrna'' figs must be interplanted with 5% caprifigs. ''Kadota'' and ''San Pedro'' figs are formed by parthenocarpy.

B. Cultivars

There are many fig cultivars, but only *Ficus carica* of the *Moraceae* family is grown commercially, as a food. In the U.S., the major fig cultivars are ''Kadota'', ''Mission'', ''Adriatic'' and ''Calimyrna''. ''Kadota'' (Dottato) is small, practically seedless and creamy amber when ripe. The ''Black Mission'' has a blue-black color when ripe and has small seeds. It is marketed both fresh and dried. The ''Adriatic'' is called ''white'' because of its lightness even after drying. The ''Smyrna'' is a large white fig, principally grown in California and the Mediterranean countries for drying. It has excellent flavor, and is attractive when packed. While ''Black Mission'' and ''Kadota'' figs are exceptionally well preserved when frozen, ''Calimyrna'' and ''Brown Turkey'' are not suitable for freezing. ''Conadria'' is a fine-favored white fig that may be blushed with violet. The pulp is white to red colored.[25] Knight[11] mentioned several other fig cultivars bearing parthenocarpic fruit, e.g., ''Celeste'' (small- to medium-sized, white to purplish-brown figs with whitish to rose-colored flesh — firm, sweet, and of excellent quality), ''Magnolia'' (large-sized, amber-colored fruit with excellent canning quality), and ''Turkey'' or ''Brown Turkey'' (medium- to large-sized, pear-shaped and coppery-brown colored fruit with white or slightly amber-colored flesh).

C. Production and Distribution

Figs are grown commercially in most of the countries bordering the Mediterranean sea. Spain and Italy together produce more than two-thirds of the world's harvest. It is also grown in the U.S. and India. Although Italy was once the world's leading producer of figs, in recent years, Turkey and Greece have become the largest producers of figs, having produced 60,000 and 22,000 metric tonnes of figs, respectively, in 1976. The production figures of the U.S. and Italy during 1975-77 were 11,500 and 8,200 metric tonnes, respectively.

II. PHYSIOLOGY AND BIOCHEMISTRY

A. Growth and Development

The sugar content of figs increases gradually during the early stages of fruit development and during the later stages.[2] The glucose content of figs is always greater than the fructose,

Table 1
NUTRIENT COMPOSITION OF DRIED FIGS

Constituent	Calimyrna	Mission
Protein[a]	3.00	2.82
Carbohydrate[a]	58.20	50.10
Fat[a]	1.90	0.90
Energy (cal)	253	212
Vitamin C[b]	3.6	3.6
Vitamin B_1[b]	0.079	0.061
Vitamin B_2[b]	0.083	0.078
Vitamin A (IU)	142	92
Niacin[b]	0.71	0.59
Calcium[b]	174	130
Iron[b]	2.5	2.4
Phosphorus[b]	70	57
Magnesium[b]	60	59
Copper[b]	0.34	0.32
Zinc[b]	0.48	0.43
Potassium[b]	682	575
Sodium[b]	10	10

[a] Percent.
[b] mg percent.

Data from Bolin, H. R. and King, A. D., Jr.[2] and Watt, B. K. and Merrill, A. L.[32]

irrespective of cultivar and harvesting time.[16] As the fruits mature, there is a slight decrease in the polysaccharides, crude fiber, and protein. The sugar distribution in the dried figs is about 50% glucose, 35% fructose, and 10% sucrose.[7] Hirai et al.[10] reported that the reducing sugars in mature figs could be increased if the fruits are treated with linolenic acid, which accelerates maturation. The major acid in immature figs is citric, which drops to 50% during maturation.[30] The immature "Kadota" figs contain about 13% protein on a dry weight basis at about 2 months before harvest. The protein content then decreases slowly during development for about 6 weeks, and rapidly thereafter to 3.9%.[16] Puech et al.[22] studied the skin pigments of the "Black Mission" figs and reported the presence of chlorophyll a and b, beta-carotene, leutin, violaxanthin, and neoxanthin in the immature green-colored fruit and in the ripe blue-black fig. These workers earlier had reported that the application of ethephon to "Mission" fig fruits, at or after a certain critical stage of development, caused ripening within a week. This was associated with a rapid reduction in the epidermal levels of chlorophyll a and b, beta-carotene, leutin, neoxanthin, and violaxanthin, and an increase in anthocyanin biosynthesis and accumulation.[22]

B. Ripening and Senescence

Significant biochemical changes in the flavor, pigments, carbohydrates, acids, protein, and vitamins and minerals take place during the ripening and senescent processes of figs. Fruit extract contains peroxidase and oxygenase.[18] The proteolytic enzyme, ficin, has been obtained from the latex present in the vegetative tissue and in the outer layer of the fruit.[31] Other enzymes isolated from fig latex include peroxidase[8] and lysozyme.[9] Fresh fig latex also contains alpha and beta-galactosidase, alpha-mannosidase, and beta-N-acetylhexosamine.[12] The endo-beta-N-acetyl glucosaminidases have also been isolated from the fig.[4,17]

The nutrient composition of "Calimyrna" and "Mission" dried figs given in Table 1, indicates that figs are nutritious and good sources of carbohydrate (energy), dietary fiber,

and minerals such as potassium. Although figs are not abundant sources of vitamins, they do contain most of the recognized vitamins and minerals other than potassium. Dried figs are an especially high-energy food due to their high carbohydrate content.

III. POSTHARVEST LOSSES (CAUSES)

A. Physical Injury

Figs are very perishable and can be easily injured. Heavy orchard and market losses may be incurred due to cracks or crevices at the eye-end of the fig. These cracks may be so deep that the affected fruit may split in half.[6,21] Pantastico et al.[20] stated that splitting varies from orchard to orchard but is apparently associated with fruit turgidity as a result of dampness, rainfall, or cool weather. They recommended careful handling and packing of figs during dry weather, which may reduce splitting incidence.

B. Diseases and Pests

Figs are affected by "surface mold" (smudge) and "spot-rot". Circular, small, brown-to-black spots scatter over the entire surface of the affected fruits as they approach maturity. The associated "spot rot" is shallow in depth. Each disease has been reported only on Kadota fruits and is more severe following periods of high humidity. One or more species of *Cladosporium* and *Alternaria* fungi, have been associated with surface mold. The rotting of fruit, including the spot rot syndrome, is attributed primarily to species of *Alternaria*, whereas *Cladosporium* generally predominates in smudge lesions. *C. herbarum* Link and *A. tenuis* are known to be the causal agents in these disorders. Endosepsis (internal rot, brown rot, soft rot) of figs is caused by the fungus *Fusarium moniliforme* Sheldon. Smut and mold of fruits are world wide in both edible and caprifigs. Smut *(Aspergillus niger* van Tiegh) appears as black powdery masses of spores in the pulp of the fruit cavity, and mold *(Botrytis, Hormodendron, Penicillium,* and *Rhizopus* sp.) appears as pulp discolored gray, greenish or yellowish.[33]

IV. LOSS REDUCTION BIOTECHNOLOGY

A. Harvesting, Handling, and Maturity

Dried figs are harvested in the autumn by picking them from the ground, where they fall after they have become ripe and somewhat dry. While in most countries this is a hand operation, in the U.S. the harvesting process is mechanized.[2] Wind machines mounted on trailers are sometimes used to gently blow against the trees, causing only the ripe fruits to drop. A sweeper then mechanically removes the figs from the ground and conveys them into bulk bins. Fresh figs are hand-picked from the trees, sorted, carefully packed in small boxes and refrigerated for shipment to retail markets. A good harvest is of about 12 tons/ha fresh figs. These are soaked for a half minute in boiling salt water, dried for a few hours in the sun and for 8 days under shade. The weight of figs in this process is reduced to a little over one-third of the fresh weight.

The harvest maturity of figs is based on color and firmness. "Black Mission" figs should be light to dark purple, rather than full black, and should yield to slight pressure rather than being soft ripe. "Calimyrna" white fig should be yellowish-white to light yellow, and firm to slightly yielding for best harvest maturity.[24]

B. Low-Temperature Storage

The recommended temperatures and relative humidity for cold storage of figs are 0°C to 1.7°C and 85 to 90% relative humidity.[21] Figs thus stored can remain in marketable condition for 7 weeks, although they lose about 11.5% of their weight during this period. Lutz and

Hardenburg[11] reported that figs can be stored at −0.6 to 0°C and 85-90% relative humidity only for about 7 to 10 days. These authors recommended that the fruit should be precooled as quickly as possible to 0°C and held at this temperature during transport. McDowell and Eaton[15] stated that 2.2 to 3.3°C are more realistic temperatures and recommended air-shipment for the transport of figs.

C. Controlled-Atmosphere (CA) Storage

Several supplements to refrigeration of figs have been studied. Brooks et al.[3] recommended using 1000 lb of dry ice per carload as an aid in controlling decay, as is generally used for cherries. The concentration of 15 to 30% CO_2 obtained was eventually reduced to 1 to 2%. Condit[6] reported that coating the figs with paraffin or mineral oil lengthened their storage life. Claypool and Ozbek[5] reported that preliminary treatment of figs with 100% CO_2 was not very effective in controlling the postharvest decay. These authors suggested that figs should be stored in CO_2-enriched atmospheres to extend their marketable life.

D. Chemical Control of Losses

Fresh fruits marketed as "high moisture" figs (greater than 27% moisture) are generally sprayed with a potassium sorbate solution to reduce the chance of mold and yeast spoilage.[2] The figs so treated commonly contained about 200 to 300 ppm of sorbic acid.

Surface mold or smudge can be effectively controlled by application of carbamate or copper sprays at intervals of 2 to 3 weeks or more. Cook[33] reported that spot-rot is rather difficult to control by fungicidal applications, although Dithane Z 78® spray (2 lb/gal of water) or Zimate dust (5% Dithane Z 78) has been reported to reduce losses in experimental studies. Cook recommended that figs be harvested more frequently to prevent exposure of overmature fruit to infection.

The internal rot, brown rot, or soft rot (endosepsis) of figs can be controlled chemically by dipping fruits in 50% benomyl solution (11.4 g/25 gal of water) for 20 min. Stewart[29] reported that ripening of "Black Mission" figs was accelerated by a water spray of 10 to 25 ppm 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). Maxie and Crane[14] also found that 2,4,5-T accelerated ripening of figs indirectly by stimulation of C_2H_4 synthesis. The stage of fruit maturity at the time of auxin application has a pronounced effect on the response of figs to the chemical treatment.[26]

Bewaji and English[1] evaluated effects of chemicals such as Benlate® (benomyl) at 0.5 lb, Manzate® (maneb) at 1.5 lb and Bravo 6F® (chlorothalonil) at 3 pt/100 gal as three foliar sprays on Kadota (Dottato) fig trees. They found that chlorothalonil gave the best control of *Alternaria* surface rot. The rot at harvest and after storage with this chemical treatment was 2.8 and 8.2%, respectively, compared with 27 and 64.1% for unsprayed controls.

E. Processing of Figs

Since figs are very perishable and difficult to transport, and cannot be stored long even under refrigeration, they are most suitable for processing into canned, dried or frozen products depending upon the cultivar. Rodriguez et al.[23] reported that fruits of medium and uniform size and of good flavor and color are suitable for processing. Further, they should have tender but firm flesh, thin skin, and a small seed cavity for canning and freezing. The fruits at the firm-ripe stage are picked for canning. A large white fruit of "Smyrna" variety is preferably grown for drying. "Kadota" is primarily a canning variety, and is dried to a limited extent. The color, flavor, and texture on fully ripened "Black Mission" and "Kadota" figs are exceptionally well preserved when frozen either as slices packed with sugar or whole in a light sugar syrup. "Calimyrna" and "Brown Turkey" are not suitable for freezing, the former because of this thick skin and the latter on account of inferior flavor and tendency to discolor. "Mission" and "San Pedro" are generally marketed fresh.

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Processing of figs consists of cleaning, washing, sorting, hydrating if required, and packaging. In the U.S. the bulk of the crop (85 to 90%) is dried with about 10% being canned and less than 3% marketed fresh.[2] Approximately 2% of figs in the world are dried, the rest being consumed either fresh or in processed form.

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Chapter 7

PASSION FRUIT

I. INTRODUCTION

Passiflora is a genus with several edible species. The best known is purple passion fruit, *Passiflora edulis*, originated in South America. It thrives well in the subtropics and in tropical highlands, e.g., in Kenya at 2000 m or even higher. A yellow form, *P. edulis* (cultivar Flavicarpa), with very aromatic and rather acid juice, is better adapted to the tropical lowlands.

A. Botany

The genus *Passiflora* is mostly composed of perennial woody vines indigenous to tropical North and South America. Martin and Nakasone[15] stated that out of the 400 known species of Passiflora, about 50 to 60 bear edible fruits; only a few of these are palatable and of any commercial value. Due to the climbing nature of the plant, trellises of 2.5 meters high must be provided. The fruit is the size of a tennis ball with a hard and thick (3 to 10 mm) shell. The pulp is yellow to orange, highly aromatic, and juicy.[5,15]

B. Cultivars

In Hawaii and Fiji, the yellow passion fruit (cultivar Flavicarpa) is the basis of the entire passion fruit industry. In Australia, Ceylon, Africa, and India, the purple passion fruit or "Purple granadilla" is most exploited. "Sweet granadilla" *(P. edullis* Juss) is cultivated extensively on the mountains of Mexico and Central America. Banana passion fruit or "Tacsonia" *(P. mollissima)* is grown in the Andes.[21] "Giant granadilla" *(P. quadrangularis* L.), a melon like fruit is widely distributed throughout the tropics.[5]

The "Redlands Triangular" (Selection 3-1) and "Selection E-23" are the hybrid cultivars between purple and yellow passion fruit grown in Queensland.[10] A cultivar, "Noel's Special", with a large-fruited yellow passion fruit has been introduced by the University of Hawaii. This cultivar has an unusually bright orange-colored juice and is tolerant to *Alternaria* brown spot.[11]

C. Production

No reliable production statistics of passion fruit crop are available.

II. PHYSIOLOGY AND BIOCHEMISTRY

A. Growth and Development

Pruthi[18] reviewed information on physiological and chemical changes during ontogeny of the purple passion fruit. Immature fruits of yellowish-green stage have low juice, sugars, ascorbic acid, and carotene. These fruits are more acidic and inferior in flavor than the partially and fully mature fruits. The physicochemical characteristics of the partially and fully mature fruits do not vary markedly, with the exception that fully mature fruits possess better aroma. As the immature fruits are developed into fully mature fruits, the carotenoids and anthocyanins increase; the ascorbic acid content of the rind decreases from 111.6 to 88.6 mg%, but increases in the fruit juice from 15.3 to 33.5 mg%. There is a decrease in the total protein content of the juice from 1.03 to 7%.[5]

Table 1
NUTRITIVE COMPOSITION OF PASSION FRUITS[a]

Constituents	Wenkam and Miller[27]		Martin and Nakasone[15]		Leung et al.[13]	
	P. endulis	*P. endulis F. flavicarpa*	*P. mollissima*	*P. quadrangularis*	*P. laurifllia*	*P. foetia*
Water (%)	85.6	84.9	92.0	88.0	81.0	82.0
Energy (cal)	51	53	25	41	73	64
Protein (g)	0.4	0.7	0.6	0.9	0.6	1.8
Fat (g)	0.1	0.2	0.1	0.2	0.1	0.4
Carbohydrate						
Total (g)	13.6	13.7	6.3	10.1	17.9	15.2
Fiber (g)	0	0.2	0.3	0	0.2	—
Ash (g)	0.3	0.5	0.7	0.9	0.4	0.6
Calcium (mg)	3.6	3.8	4.0	10.0	4.0	20.0
Phosphorus (mg)	12.5	24.6	20.0	22.0	14.0	48.0
Iron (mg)	0.2	0.4	0.4	0.6	0.4	0.7
Sodium (mg)	—	—	—	—	18	3
Potassium (mg)	—	—	—	—	49	341
Vitamin A (IU)	717	2410	1700	70	880	0
Thiamin (mg)	trace	trace	0	0	trace	0.01
Riboflavin (mg)	0.1	0.1	—	—	—	—
Niacin (mg)	1.5	2.2	2.5	2.7	1.4	1.4
Ascorbic acid (mg)	30	20	70	20	20	15

[a] Constituents expressed per 100 g of edible portion.

B. Ripening and Senescence

Akamine et al.[2] reported that the purple passion fruit exhibited a typical climacteric respiration pattern, and the fruit emanated unusually large quantities of ethylene (370 microlitre/kg/hr) under ordinary (25°C) conditions. Upon ripening, the passion fruits fall from the vine, and fallen fruits are picked from the ground. The juice of ripe passion fruit contains catalase[23] and pectinmethylesterase.[19] These enzymes can be inactivated by heating at 79° and 80°C for 75 and 60 sec, respectively. The volatile constituents of yellow passion fruit consist of ethyl butyrate, ethyl hexanoate, hexyl butyrate, and hexyl hexanoate. These four esters make up 95% of the volatile oil, with hexyl hexanoate as the predominant constituent.[9] Murray et al.[16a,16b] identified 73 volatile constituents, using the coupled gas chromatograph-mass spectrometer system.

The nutrient composition of six species of passion fruit given in Table 1 shows that *P. edulis f. flavicarpa* and *P. mollissima* are excellent sources, *P. edulis* a good source, and the rest of the species fair sources of ascorbic acid. Passion fruits are also a fair to good source of riboflavin and niacin. Chan et al.[7] compared the purple and yellow passion fruits for nonvolatile (citric, malic, lactic, malonic, succinic, and ascorbic) acids, and total volatile and titratable acids were determined employing thin-layer and gas-chromatographic techniques. Yellow passion fruit predominates in most nonvolatile organic acids, especially citric (about 83% of the acids) and malic (about 16%) and in total titratable acids (Table 2). The relative abundance of each organic acid in the two types of passion fruit differed considerably.

III. POSTHARVEST LOSSES (CAUSES)

A. Physical Injury

Severe malformation and distortion of fruits sometimes result from thickening and hardening of the pericarp. Noticeable by their uneven shape, fruits often split, and callus is

Table 2
QUANTITATIVE DETERMINATION OF ORGANIC ACIDS IN PASSION FRUIT[a]

Acids	*P. edulis F. flavicarpa* (meq/100 g)	*P. edulis* (meq/100 g)
Non-volatile acids		
Citric	55.00	13.10
Malic	10.55	3.86
Lactic	0.58	7.49
Malonic	0.13	4.95
Succinic	Trace	2.42
Ascorbic	0.06	0.05
Volatile acids	0.11	0.12
Total	66.43	31.99
Titratable acids (total)	65.83	32.01

[a] Yellow passion fruit *(P. edulis F. flavicarpa)* and purple *(P. edulis)*.

From Chan, H. T., Jr., Chang, T. S. K., and Chenchin, E., *J. Agric. Food Chem.*, 20, 110, 1972. (Copyright by American Chemical Society.) With permission.

formed on the exposed surface; the disease is known as "woodiness" and is caused by a virus transmissible by aphids.[8]

B. Diseases and Pests

Apart from woodiness of passion fruit caused by a virus, no other serious diseases of the fruit have been reported. However, grease spot, bacterial spot, brown spot, and wilt are serious in certain localities. Well-defined, circular dark-green or water-soaked areas are seen on the fruit affected with green spot. *Pseudomonas passiflorae* (Reid) Burkholder has been identified as the pathogen responsible for grease spot of passion fruit. Bacterium, *Xanthomonas passiflorae* Pereira, causes the bacterial spot, in which spots, circular or irregular in shape, may appear on fruits but necrotic tissue remains superficial. An exudate that may dry into a crust is typically present and may extend over several lesions. In brown spot caused by *Alternaria passiflorae* Simmonds, the fruits suddenly wilt and sunken brown spots appear on the infected fruit.[8]

IV. LOSS REDUCTION BIOTECHNOLOGY

A. Harvesting, Handling, and Maturity

The fruit is generally not picked, but left on the vine until it falls, for full development of the flavor. The fallen fruits are gathered every morning,[24] and because of this no cover crop can be grown between the rows. The picking of mature fallen fruit from the ground at periods of 2 to 7 days is the common method of harvesting. The fruits are transported from the field in 10-kg lug boxes, and if not processed immediately, they are placed into cold storage.[1]

B. Low-Temperature Storage

Pruthi[18] recommended storage temperature of 6.5°C with a relative humidity of 85 to 90%; under these conditions, passion fruits can be stored for 4 to 5 weeks. Temperatures below 6.5°C cause chilling injury, and with temperatures higher than 6.5°C, the fruit suffers more

losses due to moldiness. Pantastico et al.[7] also recommended temperatures of 5.6 to 7.2°C and 85 to 90% relative humidity for the purple passion fruit. These authors, however, stated that under such conditions, the fruit can be stored up to 3 weeks only.

C. Chemical Control of Losses

Brown spot of passion fruit can be controlled by pruning to prevent pockets of dense foliage. The disease incidence can also be retarded by a foliar spray of 8-8-100 Bordeaux mixture, Zineb®, or maneb.[8]

D. Processing of Passion Fruit

1. Passion Fruit Juice

The processed passion fruit products are of two main types: those preserved by heat processing, and those frozen and held in cold storage until consumed. Typical examples are frozen sherbet, canned passion fruit nectar, and canned nectar combinations with citrus, pineapple, and other juices. Because of its strong acidic, aromatic, and flavor characteristics, passion fruit juice is generally diluted (1:6) when consumed as a nectar by itself or is used as a minor constituent when combined with other fruit juices. The purees or juices of orange, banana, papaya, and guava have been successfully blended with passion fruit juice into tropical fruit drinks, punches, or syrups.[4]

Passion fruit is achieving an increasing importance as a source of juice in the world market. Because of its unique and intense flavor and high acidity, it has been described as a natural concentrate. The passion fruit juice is a highly palatable beverage when sweetened and diluted, and its flavor blends excellently with other fruit juices.[22]

In Hawaii the process of extracting juice from passion fruit is well mechanized; the production capacity reaching as high as 2720 kg/hr per processing line. Chan[5] described the process as follows: ripe fruits are delivered to the processing plant in boxes or bins and dumped by lift truck into an agitated wash tank. The fruits are conveyed on a wire-mesh belt where they are washed with strong sprays of water to remove soil, dirt, etc. They are next sorted on a slow-moving conveyor to remove rotten and other unfit fruit. The rinds are sliced open by a gang of serrated, rotating, circular knives spaced 1.6 cm apart. The sliced fruit is fed into a continuous basket centrifuge with sloping walls. Juice, pulp, and seeds are forced by centrifugal action through holes in the centrifuge into the waste conveyor. A pulper fitted with 0.084 cm screen separates the seeds from the pulp and juice. The pulpy juice is then passed through a finisher fitted with a 0.05-cm screen to remove seed and fiber particles.

In Australia, passion fruit juice is extracted in several ways. In one method the juice is expressed by rotating rollers; in another, a modified apricot-pitting machine and plunger are used. In New Zealand, the halved fruits are passed over a suction device which removes the pulp and seeds.[25]

The centrifugal separator developed by Kinch[12] has greatly improved the processing efficiency. The centrifugal separator consists essentially of a basket (50.2-cm diameter) having 16° inclined perforated walls punched with 0.6-cm holes with 1.6-cm spacing. The use of pectinolytic enzymes increases juice extraction yields by 35%. Apart from its consistency, which is higher, the chemical and physical properties of the enzyme-treated juice are similar to the untreated juice.[14]

Chan[5] stated that two characteristics of passion fruit exert an important influence on processing methods. First, the flavor is extremely sensitive to heat; and heat pasteurization inevitably leads to some loss of fresh fruit flavor. Secondly, the high starch content causes accumulation of gelatinous deposits on the heating surfaces of the tabular and plate heat exchanger and a drop in efficiency of the heat exchanger, as well as deterioration of juice flavor. The heat sensitivity of passion fruit makes it difficult to heat-process the juice without

markedly changing its flavor.[20] The successful method of heat-processing the juice utilizes a spin cooker designed by L. J. Lynch of the Commonwealth Science and Industrial Research Organization, Australia.[26] The spin cooker is an inexpensive, easily constructed unit utilizing "rapid can rotation" to transfer heat quickly. The can is spun on an inclined chamber, with steam sprays impinging on the can surface. Pasteurization to an 88°C center temperature is achieved in about 1 3/4 min. The cans are then rapidly cooled with a cold water spray. The color and flavor retention in this method is far superior to those in any alternative method of heat preservation.[5,25]

Aside from the unique flavor, the comparatively high acid content of passion fruit juice is its most distinctive characteristic, and it is important in processing and formulation of products containing this fruit. The total acid content (expressed as citric acid) ranges from 2.4 to 4.8% w/w with an average 3.4% for the purple passion fruit juice.[18] The yellow passion fruit juice in Hawaii has acidity ranging from 3.0 to 5.0%, and an average 4.0% acid.[3] The predominant acid is citric acid (about 83% of the acids), followed by malic (15.9%) and lesser amounts of lactic, malonic, and succinic acids.[7]

The sugar composition of yellow passion fruit juice is: fructose 29.4%, glucose 38.1%, and sucrose 32.4%.[6] The distribution of sugars in purple passion fruit is also nearly even, as in yellow fruit: fructose 33.5%, glucose 37.1%, and sucrose 29.4%. The passion fruit juice is an excellent source of beta-carotene (provitamin A), ascorbic acid, and niacin.[5]

2. *Passion Fruit Cordials and Squashes*

These are popular beverage bases in Australia and South Africa. Carbonated beverages based on passion fruit juice have a very distinctive and attractive flavor.[22]

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Chapter 8

SAPOTA

I. INTRODUCTION

Sapota or Sapodilla is a native of tropical America having originated in Mexico or Central America.[20] It has spread to other tropical countries, e.g., southern Florida in the U.S., India, Sri Lanka, Indonesia, Burma, The Philippines, and the Caribbean Islands.[9]

A. Botany

Sapota *(Manilkara acras* L. Syn. *Achras zapota* L.) is an evergreen tree growing up to 30 meters (m) in a wild state; the cultivated types usually grow up to 10 m height. Sapota is cultivated mainly for its edible fruit, although the latex is used for chicle gum. Flowers are solitary and axillary but sometimes clustered.[4] The fruit is a fleshy berry, generally globose, conical, or oval with one or many seeds. The fruit generally weighs about 75 to 200 g, but some types produce fruit weighing almost 1 kg.[9] The fruit has a thin rusty brown scurfy skin and a yellowish brown or red pulp with a pleasant, mild aroma and an excellent taste.

The sapodilla tree is most adaptable to warm tropics but can thrive under diverse soil and climatic conditions up to an altitude of 1000 m; however, it is more prolific below 400 m. It prefers temperatures above 28°C and is dwarfed with reduced fruit production if planted in colder areas. The tree bears flowers all year round, flowering being more profuse after the rains. There are two principal seasons of production; the first is February to April, and the second is October to December.

B. Cultivars

There are several cultivars of sapodilla grown in different parts of India, U.S. and other tropical countries. In the Philippines, ''Ponderosa Chico'' is a well-known cultivar[6]. In Florida (U.S.), ''Brown sugar'', ''Modello'', ''Prolific'', and ''Russel'' are cultivated on a large scale.[3] In southern parts of India (Kerala, Tamil Nadu, and Karnataka) the following cultivars of sapota are grown: ''Badam'', ''Bangalora'', ''Baramasi'', ''Culcutta'', ''Co.I.Sapota'', ''Cricket ball'', ''Dwarpudi'', ''Gauranga'', ''Guthi'', ''Jonnavalas'', ''Kirtabarti'', ''Lon oval'', ''Oval'', ''Pala'', and ''Vivalasa''.[17] Cheema et al.[4] recognized seven cultivars of sapota grown in Western India (Gujarat, Maharashtra): ''Bhuri'', ''Dhola diwani'', ''Fingar'', ''Long Large Culcutta'', ''Kali'', and ''Vanjet''. The cultivars of sapota well known in South East India (A.P.) are: ''Ayyangar'', ''Bangalore'', ''Pot Sapota'', ''Cricket ball'', ''Dwarpudi'', ''Gauranga'', ''Jonnavalasa I'', ''Jonnavalasa II'', and ''Jonnavalasa round''. Lakshminarayana[9] stated that there is no agreement among horticulturists regarding the classification of sapota cultivars, as it is highly heterozygous. Fruit shape, size, weight, pulp color, seed number, taste, flavor, and periodicity have been used to characterize the cultivar, but seasonal changes influence the shape of the fruit to a large extent.

C. Production

The world-wide production statistics of sapota are not available. Until 1955, India was the largest producer of sapota, with more than 800 ha.[4] According to Shanmugavelu and Srinivasan,[23] sapodilla cultivation in India reached 2000 ha in 1973. Mexico, Guatemala, and Venezuela are other large producers of sapota. An average grafted 10-year old tree yields about 200 kg of fruit annually.

II. PHYSIOLOGY AND BIOCHEMISTRY

A. Growth and Development

Fruit at all stages of maturity can be found on the tree at the same time, since the tree bears flowers all year round. The pulp-to-peel ratio of sapota fruit increases during maturation,[19] the increase being attributed to seepage of water and latex from the peel to the pulp. The hemicellulose content of the fruit (as alcohol-insoluble matter) decreases as the fruit matures. Sapodilla is highly astringent when it is unripe. Lakshminarayana and Subramanyam[12] observed a gradual decrease in the polyphenol content of the fruit from fruit-set to harvest maturity. Sapodilla fruit contains large amounts of leucoanthocyanidins (pro-anthocyanidins), especially at early stages of development.[10] These workers subsequently identified the polyphenols of sapota fruit at the tender stage of two months after fruit-set.[16] The quantitative increase in polyphenols is mainly due to the increase in the fresh weight of the fruit and the dilution effect complemented by rapid synthesis of sugars and other constituents in the fruit. At immature stages, the phenolic extractives contained large amounts of chlorogenic and gallic acids. The sourness of these acids was not manifested in the overall taste of young sapota fruit. The predominant astringency of the fruit was caused by flavans. On maturation, the mellowing effect in astringency was due to the polymeric changes in polyphenols followed by the interference of sugars. Lakshminarayana et al.[11] studied changes in polyphenols of sapota as influenced by maturity. Both the qualitative and quantitative changes take place during fruit maturation. There is a significant decrease in simple polyphenols and an increase in polymeric leucoanthocyanidins. The results reported in Table 1 showed that when phenolic constituents were examined as g/fruit, all polyphenolic components increased in quantity, as the fruits matured.

B. Ripening and Senescence

Sapota takes about 8 to 9 days to ripen under tropical conditions. The edible ripe fruit soon becomes overripe and enters the stage of senescence. The fruit requires temperatures higher than 20°C to become uniformly ripe. Lakshminarayana[9] stated that extension of postharvest storage life of sapotas is one of the most difficult problems faced by the postharvest physiologists.

The nutritive composition of sapodilla fruit is given in Table 2. Indian sapota was much higher in its carbohydrate content and was about 2.5 times richer in the energy content than the Mexican Sapota. The latter, however, had higher vitamin C content. The principal chemical constituents of the mature fruit are carbohydrates and tannins. Of the carbohydrates, free sugars form a major portion, whereas starch is either absent or found in small quantities. The presence of fairly large quantities of tannins modifies the taste of the fruit and imparts an astringent flavor. The fruit also contains 1.13% of the bitter principle, sapotin.[1] The changes in total sugars, reducing sugars, and non-reducing sugar (sucrose) of sapota during fruit development are shown in Figure 1.

The hemicellulose content of sapota decreases during ripening. Part of the hemicellulose is converted to oligosaccharides, which in turn enters into carbohydrate metabolism as the ripening progresses. During this period, the sucrose content increases greatly followed by glucose and fructose. However, the sucrose is inverted to glucose and fructose during overripe stage.[12,19,25] Venkataraman and Reithel[26] studied the carbohydrate metabolism of the sapota fruit at various stages of ripening. They reported that glucose and fructose were present in all stages. They also identified three types of oligosaccharides, two of them yielding glucose, fructose, and lactose on hydrolysis. Higher oligosaccharides have been extracted from the ripe fruit, which on acid hydrolysis yield a mixture of glucose, fructose, and galactose.[22]

Unripe sapota is highly astringent; upon ripening, the presence of fairly large quantities of polyphenols still impart an astringent flavor to the fruit. At harvest, the fruit has about

Table 1
CHANGES WITH MATURITY IN POLYPHENOL CONTENT OF SAPOTA[a]

Stage of maturity (months)	Moisture (%)	Dry weight	Total extractive	Tannin content	Total phenols	Total flavans	Total lecoantho-cyanidins	Total flavans/ leucoantho-cyanidins
2	77—66	0.09	0.03	0.91	0.02	0.01	0.01	0.78
4	74—27	2.02	1.12	0.38	0.69	0.44	0.62	0.70
6	74—56	9.29	7.34	0.64	2.31	1.46	2.28	0.64
8	72—19	20.72	16.13	1.01	4.82	3.11	4.81	0.65

[a] In g/fruit.

From Lakshminarayana, S., Mathew, A. G., and Parpia, H. A. B., *J. Sci. Food Agric.*, 20, 651, 1969. With permission.

2.4% polyphenols which on ripening decreases to 1.8%.[12] The great resistance of sapota to fungal diseases is attributed to the possible presence of large quantities of polyphenols in ripe fruits.

III. POSTHARVEST LOSSES (CAUSES)

A. Mechanical Injury

The ripe sapotas are remarkably susceptible to mechanical injuries during handling and transportation. The fruit is also highly susceptible to chilling injury. The optimum refrigerated storage conditions for sapota have not been studied.[9]

B. Pests and Diseases

Sapota fruit is remarkably free of insect pests and diseases. Only two insects, viz. *Nephopteryx engraphella* Rag and an unidentified borer, have been known to attack fruits. A *Phytophthora* sp.[21] and a black yeast cause fruit rot. *Phytophthora palmivora*, the causal fungus of fruit rot is found in all parts of infected fruits, including the seeds from which pure cultures are obtained. Both the immature and ripe fruits are susceptible.[5]

IV. LOSS REDUCTION BIOTECHNOLOGY

A. Harvesting, Handling, and Maturity

It is difficult to determine the optimum maturity date for harvesting sapota fruits because of the erratic flowering habit of the crop.[9] Due to this erratic habit, fruit at all stages of maturity can be found on the tree at any one time. Fruit harvested earlier than physiological maturity take too long to soften, are low in sweetness, and highly astringent, with pockets of coagulated latex hindering the edible quality. On the other hand, fruit harvested too late soften within 2 to 3 days and are extremely difficult to handle and transport. Thus, considerable experience is required to determine to correct harvest maturity of the fruit. The fruit nearing physiological maturity, however, shed off the brown scaly external material and become practically smooth, with a yellowish tinge intermixed with a corky-brown color. Lakshminarayana[9] stated that this change could be utilized as a physical indicator of harvest time. The fruit ready to harvest when scratched with the fingernail, shows practically no green tissue or latex.

B. Low-Temperature Storage

The optimum refrigerated storage conditions for sapota are not known. Studies conducted at the Institute of Industrial and Technological Research of Central America indicated that

Table 2
NUTRIENT COMPOSITION OF RIPE SAPOTA FRUITS

Constituents	Gopalan et al.[7]	Hernandez et al.[8]
Edible portion[a]	83	86
Moisture[a]	73.7	—
Fiber[a]	2.6	—
Carbohydrate[a]	21.4	18.0
Fat[a]	1.1	1.1
Protein[a]	0.7	0.7
Energy (kcal/100 g fresh wt.)	98	38
Minerals[a]	0.5	—
Carotene (μg %)	97	—
Vitamin C[b]	6	12
Thiamin[b]	0.02	0.02
Riboflavin[b]	0.03	0.0
Niacin[b]	0.2	0.3
Calcium[b]	28	31
Phosphorus[b]	27	9
Iron[b]	2.0	1.5

[a] Percent.
[b] mg percent.

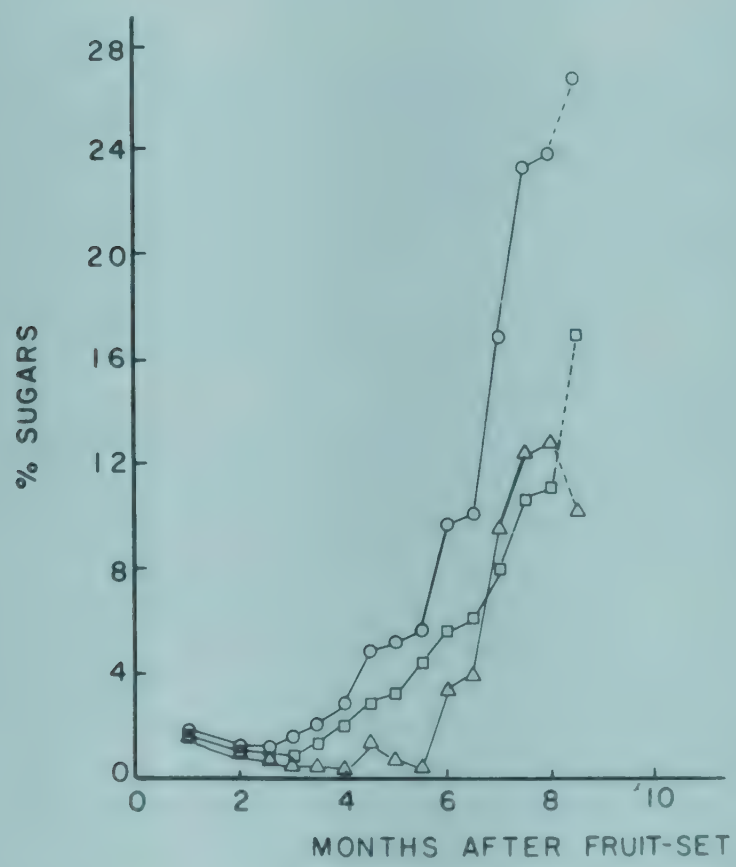

FIGURE 1. Changes in the sugar content of sapota fruit. ○: total sugars; □: reducing sugars; △: nonreducing sugars; after 8 months the changes in sugars during ripening are shown by dashed lines. (From Lakshminarayana, S. and Subramanyam, H., *J. Food Sci. Technol.*, 3, 151, 1966. With permission.)

refrigerated storage temperatures between 6° and 10°C caused irreversible damage to the fruit's ripening mechanism. Even the ripe fruits stored under refrigerated temperatures did not keep well and were poor in taste and flavor. Refrigeration and treatment with aqueous wax emulsion did not result in satisfactory ripening.[9] Pantastico et al.,[18] however, stated that ripe sapotas can be stored for about 2 weeks at 0 to 2.2°C and 85 to 90% relative humidity.

C. Chemical Control of Losses

Several preharvest and postharvest treatments with chemical growth substances have been tried to counteract the disadvantage of the erratic bearing habit of sapota crop. When a solution of 2,4-dichlorophenoxyacetic acid (100 ppm) or 2,4,5-trichlorophenoxypropionic acid (25 ppm) was sprayed 75 days before harvest, fruit ripening was hastened.[15] Similarly, maleic hydrazide (500 and 1000 ppm) spray also hastened ripening by increasing respiration and transpiration rates.[13] Foliar sprays of isopropyl-n-phenyl carbamate (IPC), however, reduced the rate of respiration, ripening, and spoilage of sapota fruit during storage. Such fruits showed better retention of ascorbic acid after ripening, but the total sugar content of the fruit sprayed with IPC (100 ppm) was decreased.[9]

Shanmugavelu et al.[24] reported that postharvest treatment of sapotas with Ethrel® in a closed chamber accelerated fruit ripening. Total phenolic and pectin contents were reduced markedly due to this treatment, causing the fruit to become edible-ripe in a shorter time than the control fruits. The Ethrel® treatment also decreased the total soluble solids, sugars, and vitamin C contents of the fruit. Obviously, further research is needed to study the postharvest behavior of sapotas and to extend the shelf life of fruits.

D. Irradiation

Studies on the feasibility of using gamma-radiation to delay the ripening of sapodillas have been reported. Sapotas irradiated at 10 krad showed an extension in storage life of 3 to 5 days at 26.7°C, and 15 days at 10.0°C. Irradiation caused no loss of ascorbic acid content of the fruits.[9]

E. Processing of Sapotas

In many countries where sapotas are grown, the fruit is mainly consumed in a fresh state. Studies conducted in India and elsewhere[2] do not promise a bright future for industrial processing of sapota fruits. The principal products tested are ready-to-serve beverages. jams, and dehydrated fruit chunks. In none of these products, is the characteristic flavor of sapota retained. In ready-to-serve beverages, the main problem is flocculation of particles of the hard tissues of the fruit.[9]

The bark of the tree contains latex, 20 to 25% of which consists of a substance called "chicle gum". The tree can be tapped once in three years yielding about 2.7 to 3.6 kg of gum. The latex is slightly aromatic, nearly tasteless, and contains 2.2% moisture, 44.8% resins, 17.2% caoutchoc (raw rubber), 6.4% gum, 9.0% sugar, 8.2% starch, and 0.2% ash.[1]

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Chapter 9

POMEGRANATE

I. INTRODUCTION

The pomegranate is native to the Middle East, and can be found in the wild state in parts of Iran and Pakistan. It has now spread to many Mediterranean countries, southern Europe, Asia, and northern Africa. It is grown all over India from Kashmir to Madras, but in the U.S., it is confined to California.

A. Botany

The fruit of the pomegranate *(Punica granatum)* is nearly round with a prominent attached calyx. Surface color varies in the few commercial cultivars from yellow with a crimson cheek, to solid brownish red, and to bright red. The edible portion is the bright-red pulp surrounding the individual seeds.[10]

Although pomegranates of high quality can be grown only where there is a cool winter and a dry summer, the tree grows under a wide range of climatic conditions. It can stand considerable frost, but is injured by temperatures below about −11.2°C. Where the winter is cool, the tree is deciduous, but on the plains of India, it is everygreen or partially deciduous. It is very drought-resistant, does well under desert conditions, but does not bear well without irrigation. On the other hand, it flourishes on land too wet for many other fruit crops.[3]

B. Cultivars

There are several types of cultivars of pomegranates. The ''white-flowered'' type is of very poor fruit quality. There are also ornamental types with double flowers, largely sterile, and not grown for fruit. The most promising cultivars grown in India are ''Paper Shell'', ''Spanish Ruby'', ''Muskat Red'', ''Vellodu'', ''Ganesh'' and recently released ''Country Large White'' and ''Shirin Anar''. Patil and Sanghavi[8] described the fruit characteristics of several cultivars of pomegranate including ''Ganesh'', ''Muskat'', ''Alandi'' and ''Dholka''. The cultivars ''Khandhar'' of Pakistan, ''Wonderful'' of Israel, ''Mangulah'' of U.A.R., ''Ahmar'', ''Aswad'', and ''Halwa'' of Iraq, and ''Paper Shell'' and ''Spanish Ruby'' and ''Early Wonderful'' (Visalia-California) are the high quality pomegranate cultivars.[1]

II. PHYSIOLOGY AND BIOCHEMISTRY

The fruit quality depends largely on the amounts of sugar and acid content of the juice. Sugar varies from about 12 to 16%, and acid from 1.5 to 2.5% in varieties grown in arid regions. In humid regions, both the sugar and acid contents are likely to be less. Siddappa and Bhatia[11] reported about 8.93% reducing sugar and 0.18% sucrose. There is also a considerable variation in the seeds, some are soft to eat, while some are large and hard.

Josan et al.[4] studied fruit set, development, and cracking in 21 cultivars of pomegranate. After open pollination, fruit set was highest in ''Dholka'' (63.8%), ''Bedana'' (63.0%), and ''Kali Shirin'' (62.7%). The fruit set was considerably lower after self-pollination. Josan et al.[4] determined fruit development at fortnightly intervals. The cultivars such as ''Kazkai'', ''Shirin Anar'', and ''Achikadana'' had the largest fruit with 6.50, 6.32, and 6.26 cm diameters, respectively. The fruit cracking was lowest in cultivars ''Kazkai'', ''Guleshah'', and ''Bedana''.

When the physiological disorder known as ''internal breakdown'' occurs in the pomegranate, the pulp-bearing seeds (arils) do not develop the typical red color and are somewhat

flattened rather than plump.[10] Flavor of the arils is abnormal and many have a streaked appearance due to fine white lines radiating from the seed. There are no external symptoms. The cause of the disorder is not known; it originates during growth in some seasons, usually only in limited areas. Du et al.[2] determined anthocyanins of pomegranate. They found that pelargonidin-3-glucoside and pelargonidin-3,5-diglucoside, which were present in minor amounts in the seed coats, were present at much higher amounts in the peel. Delphinidin-3-glucoside and delphinidin-3,5-diglucoside were not detected in the peel, while cyanidin-3-glucoside, and cyanidin-3,5-diglucoside were present in appreciable amounts.

III. POSTHARVEST LOSSES (CAUSES)

A. Physical Injury

Sunburns can cause fruit injury leading to a leathery , tough area on the rind, usually at the stem end. The injury may show only on one side or may extend completely around the fruit. Splitting and cracking may occur when the fruit is on the tree. The rind shows various degrees of cracking, which often serve as entry points for decay organisms.

B. Pests and Diseases

Three major diseases of pomegranate caused by microorganisms are "gray mold rot", "heart rot", and "*Penicillium* rot". The "gray mold rot" is caused by *Botrytis cinerea*. Decay usually starts at the calyx. As it progresses, the skin becomes light brown, tough, and leathery. The pulp-bearing seeds disintegrate into a dark mass in advanced infections. Under moist conditions, the typical gray mycelium appears on the affected surface.[10]

"Heart rot" is caused by *Aspergillus niger* and *Alternaria* sp. Affected fruits show a slightly abnormal skin color, and internally a mass of blackened arils. Usually there is a black line of decay extending from the calyx into the fruit interior. The disease develops while the fruit is on the tree. Affected fruits can usually be detected by sorters and eliminated from the commercial pack.

The "*Penicillium* rot" caused by *P. expansum* and other *Penicillium* sp. develop watery areas at the infection site, followed by masses of blue or green spores. Infections invariably occur at skin breaks caused by cracking, mechanical injuries, or insect punctures. Other fungi may infect the same injured area and eventually overgrow the *Penicillium*.

IV. LOSS REDUCTION BIOTECHNOLOGY

A. Harvesting, Handling, and Maturity

The fruit is generally clipped from the tree when ripe, and its quality improves on storing. Early harvesting in order to avoid cracking is one of the causes of poor quality of pomegranate in India.[3]

B. Low-Temperature Storage

Among tropical and subtropical fruits, the pomegranate is perhaps the only fruit having a storage life as long as that of the apple.[6] Pantastico et al.[7] recommended storage temperatures of 0 to 1.7°C and relative humidity of 85 to 90% for storing Khandhar pomegranates for 11 weeks. According to Ryall and Pentzer,[10] pomegranates are well adapted to cold storage conditions. At a temperature of 0°C with 90% relative humidity, sound fruits can remain in marketable condition for at least 8 to 9 weeks. Control of relative humidity is very critical, because the skin desiccates readily at low humidities, and hard, darkened rinds are unattractive and reduce marketability.

C. Chemical Control of Losses

A fruit rot of pomegranate following butterfly attack, said to be caused by *Phomopsis versoniana*, can be controlled effectively by spraying with cuprous oxide. Leaf and fruit spots caused by species of *Cercospora* and *Gloeosporium* are controlled by spraying with Bordeaux misture.[5]

D. Processing of Pomegranates

Pomegranates are largely used as a dessert frúit. The juice makes a delicious drink, but as the rind and carpellary membranes contain tannin, it is difficult to extract the juice without getting more tannin into it than is pleasant. This can be avoided by allowing the fruit to shrivel before crushing, or by adding gelatin to absorb the tannin.[3] When the whole fruit is cut and pressed, the juice contains 0.17% tannin, but when the grains are separated and pressed, the tannin content of the juice is 0.12%. A good variety gives about 40% juice; total solids vary from 17.3 to 18.3% of the juice, and acidity (as citric acid) varies from 0.81 to 1.23%. A juice of satisfactory quality can be prepared by heating the juice to 79.4° to 82.2°C for 30 min, cooling it quickly, and after allowing it to stand overnight, decanting or filtering the juice. The filled bottles may then be pasteurized at 79.4° to 82.2°C for 30 min, or the juice may be preserved using sodium benzoate. Hayes[3] reported that pomegranate syrup can be made by adding sugar and acid, and that a product known as ''anar rub'' with fairly good keeping quality can be made by concentrating the juice with added sugar to 75 to 80% total solids. An attractive jelly also can be prepared from the juice of pomegranate.

An attractive colored juice (purplish red), large juicy grains, mild acid-sweet taste, and a tannin content of not more than 0.25% are the qualities desired in the fruit used for the processing.[9] Pomegranate cultivar such as ''Khandhar'', ''Wonderful'', ''Mangulati'', ''Ahmar'', ''Aswad'', ''Halwa'', ''Paper Shell'', and ''Spanish Ruby'' give juice of the desired qualities and are largely used for processing. In juice extraction using a commercial hydraulic press, the pressure should be less than 100 psi on the whole fruit so as to maintain the tannin content at a fairly low level.[9]

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Chapter 10

COCONUT

I. INTRODUCTION

The coconut palm is one of the most beautiful and useful trees of tropical coastal districts; one of the lavish gifts of nature to man. Many coconuts are consumed as such in the producing countries; grated coconut meat is an indispensable ingredient of many delicious dishes in the tropical countries. The consumption of unprocessed nuts is between 18 to 50% of the output of the main producing countries and in some countries, such as Thailand, the percentage of local consumption is even higher and can reach 80 to 90% of local production.[22] The bulk of the world's coconuts, however, is dried to produce copra and is processed into coconut oil and coconut cake.

A. Botany

The coconut *(Cocos nucifera* L.) belongs to the family, *Palmae* (Palms), which constitutes one of the most important families of the Monocotyledons. The palms include many of the crops of great value to man, such as the date, coconut, oil palm, areca palm, sago palm, sugar palm, toddy palm, palmyra, etc. They are all characterized by their unbranched trunks crowned by fan-shaped, pinnate or bi-pinnate leaves. The inflorescences and fruit are usually produced in the leaf axis, but in some species at the end of the mature trunk.

The coconut palm is included in the tribe "Cocoideae", which comprises more than twenty genera. The genus *Cocos* is regarded as monotypic containing only *Cocos nucifera*.[6]

The coconut palm is monoecious; i.e., both male and female flowers are present on the same inflorescence. The latter, which is called a spadix, develops within two stout sheaths or spathes, of which the inner continues growing after the outer has ceased and therefore splits it and emerges from it. A new spadix is formed every 20 to 25 days (about 16/year). Of the 15 to 20 female flowers produced on each spadix, only 4 to 5 sets (commonly called buttons) rapidly grow to become pointed, corn-like nutlets. Each spadix bears 250 to 300 male flowers, small in comparison with the females; within about 2 weeks these fall off, 3 to 6 days before the female flowers on the same spadix become receptive to pollen. The receptive period lasts 4 to 6 days. Thus cross fertilization from a spadix opening later is ensured.

The fruit is a drupe, with a thin epicarp overlying a thick, fibrous mesocarp. The fibers of mesocarp, which are the commercial product called coir, are used to make rope, matting, baskets, etc. Inside the mesocarp is the hard shell-like endocarp, which in turn encloses the endosperm. This provides, as the fruit ripens, the white meat or copra, rich in oil, and the watery milk of the central cavity. About 5000 coconuts yield 1 metric tonne (MT) of copra, and a single ripe nut weighs 2.5 to 3 kg and attains a length of about 25 cm. The fruit is fully grown in 6 months but requires 3 to 7 months more to become mature. The coconut palm begins to bear fruit in or about the sixth year and comes into full bearing in about the 12th year, producing 80 to 150 nuts per year on particularly well-managed plantations. The embryo which develops within the nut fills the central cavity and emerges through one of the three pores (eyes) in the shell; the leaves and roots penetrate the outer layers of the fruit in opposite directions. The cotyledon, unlike a mature leaf, is undivided.[24]

B. Cultivars

The dwarf varieties of the coconut palm may be clearly differentiated. Unlike the usual tall palms, dwarfs show a degree of self-pollination and form moderately stable populations.

Tall palms are predominantly cross-pollinated and vary greatly in their characters. Apart from height, the color, size, shape, and other properties of the fruit (thickness of the husk, etc.) have been used as the principal characteristics to classify coconut cultivars. Child[6] reported that the market cultivars are duplicated in the coconut-growing countries of the Orient and the Pacific. The "Nawasi" and "Nawasi-thembili" cultivars probably correspond to that known in South India as "Kaithathali" as well as to the "Tamisan" of the Philippines. The "Dikiri-Pol" is probably the same as the Indian "Thairuthengai" and the Philippine's "Makapuno". In 'Dikiri-Pol' nuts, there is no water and the cavity is completely filled with a gelatinous curd which is very palatable. The pink husk variety, known in the Philippines as "Kalimbahim", resembles the "Ran Thembili" of Sri Lanka, and the "Guinarang" may be Sri Lanka's "Gon-Thembili". The "King" coconut is a semi-tall and quite distinctive cultivar and is probably that termed "Regia" by Rumphius and Miquel. The dwarf cultivars are not of great economic interest. In the U.S., the only well known coconut cultivar having nuts of high quality is "San Blas" from Panama.

Hybrids between tall and dwarf varieties occur in nature, and have also been produced by artificial cross-pollination. The tall × dwarf hybrid palms are vegetatively vigorous, with broad stems and a large number of leaves; about 63% of the progenies flower in less than 4 1/2 years, and develop nuts that are large and heavy, giving copra of good quality.[6] Hybrid coconuts of Tall × Dwarf, Tall × Gangabondham and Tall × Tall were compared in a 6-year trial, with "West Coast Tall".[15] The Tall × Tall hybrids were found to be the shortest. All Tall × Dwarf hybrids flowered in the sixth year, compared with only 10% of "West Coast Tall". Potty et al.[18] reported that in a comparative trial with several Indian cultivars, the "West Coast Tall" (56 nuts/tree) followed by "Laccadive Ordinary" (37 nuts/tree) were found to be promising yielders of nuts.

C. Production and Distribution

The world production of coconuts increased from 27,614 thousand MT in 1969-71 to 35,422 thousand MT in 1980.[10] The major coconut producers in 1980 were Indonesia (10,900 MT), the Philippines (1975 MT), India (4500 MT), and Sri Lanka (1550 MT). The world production of copra increased from 3842 in 1969-71 to 4552 thousand MT in 1980. The Philippines alone produced 2000 thousand MT of copra this year. In the Philippines, nearly one-third of the population depends on coconuts for its livelihood, where more than 7 billion coconuts are produced annually, about 220 per head. In Sri Lanka, with 2.5 billion nuts, the production of nuts per head comes to about 232.[22]

II. PHYSIOLOGY AND BIOCHEMISTRY

The information on the physiology and biochemistry of growth, development, and maturation of coconuts is scanty. However, the composition and properties of coconut oil, fatty acid composition, quality of edible oil, and the amino acid composition of coconut cake have been reported. Kaufmann and Thieme[13] have given the range of important fatty acids occurring in coconut oil and have shown how well it compares with the composition of palm-kernel oil (Table 1). Thieme[22] stated that coconut, palm-kernel, and Babassu-kernel oil can substitute each other for all kinds of usages and that they are in some respects competitors on the world market. The chemical and physical characteristics of the coconut oil as reported by Eckey[9] are given in Table 2.

Reddy et al.[20] tabulated data on nut weight, the percentages of fiber, pith, shell, water and kernel moisture content, oil content of dried kernel, and free fatty acid content of extracted oil of ten cultivars of coconut. The cultivar "San Ramson" produced the heaviest nuts (2670 g) and "Dwarf Green" the lightest (258 g). The percentage of kernel was highest (41%) in "Ganga Bondam", whereas "West Coast Tall" gave the highest percentage of

Table 1
FATTY ACID COMPOSITION OF COCONUT OIL AS COMPARED WITH PALM-KERNEL OIL

Fatty acid	Coconut oil	Palm-kernel oil
	(percent of total acids)	
Caproic	0.0—0.8	traces
Caprylic	7.8—9.5	2.7—4.3
Capric	4.5—9.7	3.0—7.0
Lauric	44.1—51.3	46.9—52.0
Myristic	13.1—18.5	14.1—17.5
Palmitic	7.5—10.5	6.5—8.8
Stearic	1.0—3.2	1.3—2.5
Oleic	5.0—8.2	10.5—18.5
Linoleic	1.0—2.6	0.7—1.3

From Kaufman, H. P. and Thieme, J. G.[13]

Table 2
CHEMICAL AND PHYSICAL CHARACTERISTICS OF COCONUT OIL

Characteristics	Usual range
Acid value	1.0—10.0
Saponification value	251.0—264.0
Iodine value	7.0—10.0
Thiocyanogen value	6.1—7.0
Reichert-Meissl value	6.0—8.0
Polenske value	12.0—18.0
Acetyl value	8.0—
Kirschner value	1.6—1.9
Unsaponifiable matter, (%)	0.15—0.6
Refractive index at 40°C	1.448—1.450
Specific gravity	0.917—0.919
Specific gravity (99/15.5°C)	0.869—0.874
m.p. °C	
incipient fusion	20.0—22.0
complete fusion	23.0—26.0
solidifying point, °C	22.0—23.5

From Eckey, E. W., *Vegetable Fats and Oils*, Reinhold, New York, 1954, 836. With permission.

oil in dried kernel (77%). Reddy et al.[19] collected similar data on 11 coconut cultivars. Tall × Dwarf had the heaviest nuts (995 g), followed by Dwarf × Tall (696 g). The highest amount of kernel oil was found in "Laccadive Ordinary" (70.8%), followed by "Laccadive Small" (70.4%). Swetman and Broadbent[21] reported that the sugar content of desiccated coconut prepared from four cultivars of Sri Lanka, viz. San Ramon × Malaysian Dwarf, Tall × Tall (open-pollinated), Malaysian Dwarf × Sri Lanka Tall (CRI C 65), and Tall × Tall (CRI C 60, hand pollinated), differed significantly between cultivars and also within cultivars due to storage from 0 to 5 weeks.

Hagenmaier et al.[12] reported that the protein efficiency ratios (PER) of coconut meal,

Table 3
AMINO ACID COMPOSITION OFTHE COCONUT PROTEIN FRACTIONS

Amino acid	Coconut skim milk[a] (g/16g N)	Insoluble protein[b] (g/16g N)
Essential		
Isoleucine	2.6	3.7
Leucine	5.4	6.3
Lysine	4.6	2.6
Phenylalanine	3.8	4.1
Tyrosine	2.3	2.9
Cysteine	1.7	1.3
Methionine	1.3	2.2
Threonine	2.4	3.3
Tryptophan	0.9	1.1
Valine	4.0	4.9
Non essential		
Histidine	2.2	1.4
Arginine	15.5	13.1
Aspartic acid	7.1	8.2
Glutamic acid	22.0	15.2
Serine	3.7	4.6
Proline	3.5	3.6
Alanine	4.1	3.9
Glycine	3.8	3.8
Total	90.9	86.2

[a] From Hagenmaier et al.[11]
[b] From Hagenmaier et al.[12]

concentrated coconut skim milk, and spray-dried coconut skim milk were 2.11, 1.98, and 1.67, respectively. Data reported in Table 3 indicate that the most limiting amino acids of coconut skim milk are isoleucine, methionine, and threonine (based on egg values), or methionine, isoleucine, and tryptophan (based on the FAO pattern). All these limiting amino acids are, however, higher in the insoluble protein (Table 3). Hagenmaier et al.[12] suggested that the reduced PER of concerned coconut skim milk, as compared to whole coconut protein was accounted for by protein fractionation, rather than by processing conditions. Hagenmaier et al.[11] previously reported that spray-drying of coconut skim milk at an air outlet temperature of 107°C and above caused reduction in available lysine.

III. POSTHARVEST LOSSES (PESTS AND DISEASES)

The monograph of Lepesme[14] as quoted by Lever (1969) mentioned about 750 species of insects associated with the coconut palm, and indicated that over one fifth of these are specific to it. Lever[24] dealt with 110 species of insect-pests attacking the palm in the field. In addition, there are pests attacking copra in storage and other non-insect pests and diseases. *Cadra Cautella*, Walker (widely known as *Ephestia cautella)* is a well-known pest of oily vegetable products such as cocoa beans, cotton, seed, nuts, and copra, and also of dried fruits, especially the figs. As a pest of copra, it is injurious mainly when this product is not properly dried and suitably stored. The insect is strongly attracted to the molds which thrive on poor-quality copra. The caterpillars are commonly found in the crowns of the trees, feeding on both male and female flowers and on the ripe fruit.[3] *Necrobia rufipes* de Geer

is a common beetle, especially in the wet season, in copra stores (but not on dried copra). In Southeast Asia and the Pacific countries it is popularly known as the "copra bug". It is a serious pest of badly prepared, moldy copra, but not of high-quality properly prepared copra. This insect can serve as an indicator of the degree of inefficiency and uncleanliness of copra stores.[24]

Much of the deterioration of copras during transport, storage, and shipment is practically always due to careless preparation with insufficient drying. The fungal and insect damage to copra have been reviewed by Passmore,[17] Corbett et al.,[8] Ward,[23] Cooke,[7] and more recently by Lever.[24]

Bacterial infection occurs on coconut meat containing 20% or more of moisture. It commonly occurs between the splitting of the nuts and the commencement of sun-drying or heating in the kiln. This period must be kept to a minimum and should not exceed 4 hr. Child[6] stated that four types of fungi can attack copra; their relative proportion depends upon the moisture content of the copra:

1. On copra with low moisture content (7% or below), only a superficial growth of "green mold" may be found, which may include *Penicillium glaucum* Link, green *Aspergillus glaucus,* and other *Aspergillus* sp.
2. The brown and yellow molds (Aspergilli of several groups) prefer an intermediate moisture content, 8 to 12%.
3. The black Aspergilli, represented by *A. niger,* occur when moisture content of copra is above 12%; they produce black spore bodies, giving the mold and copra a black color.
4. White mold *(Rhizopus* sp.) occurs only upon wet copra and forms masses of white mycelium.

Considerable losses in weight can occur during storage and transport of imperfectly dried copra, from actual decomposition caused by mold and sometimes followed by further loss due to insect damage. Apart from the actual consumption of material by insects, the pests cause the accumulation of "dust" — the term applied to the extraneous disintegrated material in a sample of copra. Samples of dust examined by Passmore[17] invariably contained insects or traces of insects.

The oil from inferior mold-affected copra is liable to be rancid, colored, and of high free fatty acid content, decreasing its quality; such oil may need considerable refining and its yield may be abnormally high. Child[6] ascribed these high oil percentages to the fact that the inside layers having the lowest oil content are removed. Copra made from the kernel remaining in seven-month-old seedlings may have an oil content as high as 77%. The coconut cake (poonac) from severely deteriorated copra is of little use as cattle cake. Thus, the ultimate losses in actual weight, quality of oil, and value of press cake, may add up to a serious amount, which is not always reflected in the price differences between high- and inferior-quality copras.

IV. LOSS REDUCTION BIOTECHNOLOGY

A. Harvesting, Handling, and Maturity

To obtain the maximum quantity of good quality copra, nuts must be harvested fully ripe. For "ball" copra, it is even desirable to allow the nuts to fall naturally and thus ensure complete maturity. Ripe nuts are also essential for manufacture of desiccated coconut.

In South India, the stage of ripeness at which nuts can be harvested is modified by the requirements of coir manufacture. Green husks are used and the nuts are picked about a month short of full maturity, i.e. at about 11 months from setting of the female flowers.

The income from green husks from coir offsets the shortfall in the amount and quality of the copra produced. Child[6] recommended that nuts should be picked only after 11 months of maturity.

Coconuts are picked by human climbers or cut by the use of knives attached to the end of long bamboo poles. One species of monkey, *Macaca nemestrina* L. (the pig-tailed monkey) is said to have been trained to climb trees and to throw nuts down, in Sarawak and Indonesia. Aziz and Davis[1] reviewed and discussed the use of macaque *(Macaca nemestrina)* monkeys to replace difficult-to-obtain human labor for harvesting coconuts, arecanuts, and other fruits which are not easily accessible. Data on harvesting coconuts in West Sumatra between 1970 and 1976 showed that 70 to 80% of all nuts were harvested by monkeys. Aziz and Davis[1] have outlined the training of monkeys. In the Pacific Islands it is a common practice to allow the nuts to fall naturally and to collect them from the ground. Trials conducted in Sri Lanka showed that fallen nuts give a slightly better out-turn of copra with only a slightly higher proportion of off-grade copra.

In countries where the coconut industry is less commercially developed, the nuts are cut in half with an axe or knife through the husk and shell, and the meat is separated either wet or, more easily, after partial sundrying. It is always desirable to separate the husk (even if not sold for coir manufacture). Baboo[2] developed an improved model of coconut dehusker. The implement can dehusk coconuts of any shape and size with nut breakage of about 1%. It was reported that 1, 2, and 3 operators dehusked 500, 1600, and 3000 nuts, respectively, in 8 hr using the model coconut dehusker. The operation of the dehusker involves 6 movements which can be shared by 2 or 3 operators. The nuts are split easily by a sharp crack with a machete applied at its ''equator''. A skilled man can split up about 10,000 nuts in a day. The copras are then cured, sun-dried, or kiln-dried to reduce moisture content.

B. Drying of Copra

Child[5] concluded that copra dried to 6 to 7% of moisture and stored in a well-ventilated dry storage place (godown) at an uniform temperature will not seriously deteriorate. There is little gain by drying copras below 6%; even a moisture of 8% need not cause serious trouble if subsequent storage conditions are satisfactory. Excessive mold growth is observed when the relative humidity is greater than 85% at room temperature (28.5 ± 3.5°C), or greater than 95% at 40°C.[4]

C. Chemical Control of Losses

When inferior copra is stored, insect damage can be minimized by treating sacs with DDT or other suitable insecticides. Fumigation with SO_2 may also be resorted to. Fumigation has been practiced on ships carrying copra from the Philippines to the U.S. A mixture of 99% CO_2 and 1% ethylene oxide has been found to be effective against several insect pests of copra.[6] Lever[24] recommended regular chemical treatment of the floor and walls for disinfecting storage sheds and to ensure an insect population at a low and harmless level. To every 100 m^2, 5 ℓ of a mixture of 170 g of 25% Lindane® (BHC) dispersible powder and 225 g of 50% DDT wettable powder in water should be applied by spraying. A malathion spray can also be used as an alternative, at 450 g of 25% malathion dispersible powder in 5 ℓ of water per 100 m^2 of floor and walls applied monthly. The proper storage hygiene is very essential.

Nathan et al.[16] tested several chemicals for preventing fungal infection (pathogen unspecified) during sun- and shade-drying of coconuts. The glacial acetic acid applied as a thin coat on the exposed surface of the coconut kernel prevented fungus growth for 36 to 38 hr. When the relative humidity was more than 90%, the treatment had to be repeated 3 times every 5 days to obtain fungus-free copra. The chemical treatment had no appreciably adverse effects on copra, oil, or cake flavor.

D. Processing of Coconut

Coconut can be processed into coconut oil, coconut cake (poonac), desiccated coconut, coir, and coir manufactures. Thieme[22] reviewed the literature on coconut oil processing, describing various methods of processing, preparatory equipment, oil extraction equipment, refining of coconut oil, and properties and usage of coconut oil and coconut cake.

1. Coconut Oil

In order to obtain pure coconut oil, the water is removed either by drying the meat before processing or by separating the extracted milk into oil and water by special processes. Two methods are used to extract coconut oil: (1) dry processing, and (2) wet processing. Dry processing is simpler, and practically all commercial coconut oil is processed from previously dried coconut endosperm called ''copra''. Strangely enough, some of the oldest primitive methods are based on less simple wet methods, which are used in rural districts of developing countries. In recent years, however, a new interest has arisen in the wet processing of fresh coconut with the availability of modern equipment and scientific methods. The wet processing of fresh meat, therefore, represents both the oldest and most modern method of coconut oil processing. The reason for this interesting development is entirely in the nutritional field. By the wet processing of fresh coconuts, the protein of the coconut can be obtained in a form suitable for human consumption.[22]

The hydraulic presses introduced at the beginning of the 19th century can extract oil continuously. Similarly, solvents (light paraffinic petroleum fractions such as hexane, trichloroethane) are also used to extract oil in modern methods, e.g., bath extraction, continuous extraction, and a combination of an expeller with a solvent plant.

Good, fresh coconut oil is light colored with a pleasant taste and aroma, and is consumed in many developing countries without any refining. However, there is an increasing demand for the water-white, tasteless and odorless refined oil. Coconut oil is rather easy to refine. The refining of oil removes from the oil (1) the free fatty acids and the gums in order to improve taste and brightness, (2) coloring matter to get water-white or at least light-colored oil (by bleaching), and (3) all objectionable odors by deodorizing. The by-product, soap stack, forms a good raw material for soap.

2. Coconut Oilcake

Coconut oilcake, the residue after extraction of the oil from copra, is a most important by-product of the processing of coconut oil. Before the introduction of expellers, coconut cakes were produced from hydraulic presses in the form of slabs about 35 to 40 cm square and 2.5 to 3.5 cm thick. Expeller cakes have the form of broken flakes or fragments and are disintegrated into meal; the residue from solvent extraction is a fine meal.[22] The chief uses of coconut cake are as a cattle feed and fertilizer, and there is a possibility of using cake as protein for man. Swetman and Broadbent[21] suggested that as far as the sugar content is concerned, coconuts should be processed not later than one week after harvesting.

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Chapter 11

LYCHEE

I. INTRODUCTION

The origin of the lychee is believed to be in China's Kwantung Province,[22] where it has been grown for as long as 40 centuries.[23] Lychee is consumed fresh and in preserved forms. The edible portion of the fruit is a white to cream-colored translucent pulp surrounding a glassy brown seed. The pulp is grape-like in texture, very succulent, and aromatic and is characterized by sweet and acid tastes.[5]

A. Botany

Lychee *(Litchi chinensis* Sonn) is a subtropical evergreen belonging to the family *Sapindaceae* or Soapberry. The fruit is borne in bunches on trees that may reach 9 to 12 m in height. The pericarp of the mature fruit is thin, hard, and somewhat warty in texture. Depending on cultivar the pericarp may be pale green, bright red, or rose-colored. Round to oval in shape, the individual fruit measures about 2.5 to 4 cm. Morcottage (air layering) is the most common form of lychee propagation, with budding and grafting being practiced to a limited extent. The fruit production begins about the 4th year, and seedling trees do not bear until about 8th or 9th year, sometimes not at all.

B. Cultivars

Lychee cultivars vary in their fruit color, size, shape, and seed size. Groff,[13] Huang,[15] and Yee[30] documented and described the important cultivars of lychee. ''No Mi Ts'Z'' or ''No Mai T'sz'' (Glutinous rice) are names for one superior cultivar described by Huang[15] in Taiwan. Groff[13] reported ''Kua Lu'' or ''Kwa Luk'' (Hanging green) as the most famous cultivar of the time. ''Kuei Wei'' or ''Kwai Mi'' (Cinnamon flavor) is found both in China and Taiwan[15] and in Hawaii.[30] ''Hsiong Li'' or ''Heung Lai'' (Fragrant lychee) is noted for its small seed, a desirable characteristic. Singh and Singh[25] reported that the most famous cultivar in China is ''Chen Purple'', also known as ''Chen Family Purple'', ''Chen Tsz'' or ''Chen Tze'' in the U.S.; this cultivar is known as ''Brewster'', for Rev. W. N. Brewster who obtained it from Hengwhat in the Province of Fukien.[11] It is the most widely grown cultivar in the U.S. Higgins,[14] Singh and Singh,[25] and Mathew and Pushpa[21] described the Indian cultivars. The Groff cultivar, developed in Hawaii, is a late-bearing cultivar characterized by shrivelled seeds. Shrivelled or aborted seed, sometimes called ''chicken-tongued'', is a desirable characteristic, because that fruit has a high percentage of flesh.[5]

''Dehra Dun'', ''Early Large Red'', ''Kalkattia'', and ''Rose-scented'' are the important cultivars of lychee grown in Saharanpur and Dehra Dun (India). ''Mauritius'' is the only lychee cultivar grown in South Africa on a commercial scale.[17]

C. Production and Distribution

During the 1950s Kwantung and Fukien Provinces in China were the largest producers of lychee, followed by India.[25] Smaller plantings are found in South Africa, Burma, the West Indies, New Zealand, Brazil, Honduras, Japan, Australia, Madagascar, and the U.S. (Florida and Hawaii).

II. PHYSIOLOGY AND BIOCHEMISTRY

The composition of lychee varies greatly. The moisture content ranges from 77 to 83%.

Wenkam and Miller[29] reported 81.0% and 77.6% moisture, respectively, for "Brewster" and "Kwai Mi". Mathew and Pushpa[21] reported 83 to 87% moisture in 6 Indian varieties. Most analyses showed that the protein content of lychee may vary from about 0.8 to 1.5%.[5] The fat content of the fruit is also negligible, less than about 1%. The sugar content of lychee varied considerably, 11.8% in "Hak Ip" to 20.6% in "Kwai Mi".[29] Most Indian varieties range in their sugar content from 10 to 13%. Higgins[14] reported that the total sugar content of the lychee was 15.3%, consisting of 81.7% reducing sugar and 18.3% sucrose. Mathew and Pushpa[21] observed that total sugars in 6 Indian varieties ranged from 55.92 to 61.37% of the fruit on dry basis, reducing sugars accounting for 41.52 to 43.45%. Thus, slightly more than 70% of the sugar was found to be the reducing sugar. Stahl[26] and Chan et al.[10] demonstrated the presence of invertase. These authors postulated that if this enzyme is not inactivated when the fruit is macerated prior to analysis, it may catalyze inversion of sucrose, giving higher proportions of reducing sugars in the analyses. The lychee invertase has a pH optimum of 2.6, lower than the pH of the fruit pulp (pH 4.6); the optimum temperature for the enzyme is 55°C.[10] Chan et al.[10] quantified lychee sugars and found that fructose, D-glucose (expressed as total glucose) and sucrose were present to the extent of 3.154, 5.036, and 8.562%, respectively, in the fruit. The total sugars amounted to 16.752%.

The fruit acidity ranged from 0.20 to 0.64% for 12 Indian cultivars.[25] Values as high as 1.1% acid were reported in the juice expressed from an unidentified variety in South Africa.[20] Acidity decreased during fruit ripening,[1,16] and following the harvest, acidity again decreased during storage.[15] The Brix/acid ratio increased during ripening and storage, and reached 80:1 before rotting set in.[16] The predominant nonvolatile acid in lychee was malic acid, accounting for about 80% of the total nonvolatile acids.[9] The others (about 20%) comprised of citric, succinic, levulinic, phosphoric, glutaric, malonic, and lactic acids (Table 1).

Lychee is an excellent source of ascorbic acid, but its content varies considerably.[5] Wenkam and Miller[29] found 40.2 mg/100 g of ascorbic acid in "Kwai Mi" and 80.8 mg/100 g in Brewster. Chadha and Rajpoot[6] reported 44 mg/100 g in "Culcutta Late", and Thompson[28] found 90 mg/100 g of ascorbic acid in an unspecified variety. The ascorbic acid content decreased as the temperature and storage time increased.[28] Lychee is not a significant source of thiamin, riboflavin, calcium, phosphorus, or iron, and it lacks completely in carotenes.[5]

III. POSTHARVEST LOSSES

The reports on postharvest losses of lychee are scanty. Cook[12] reported canker and root rot, and leaf spot diseases of lychee caused by *Otryodiplodia theobromae*, *Colletotrichum gloeosporioides*, and *Pestalotis pauciseta* Sacc. Partial control of these diseases is achieved in India with spray applications of either sulfur or Boreaux mixture (2-2-50).

IV. LOSS REDUCTION BIOTECHNOLOGY

A. Utilization and Processing of Lychee

Although most desirable as a fresh fruit, lychee can be preserved in a number of ways.[5] Dried lychees are known as "litchi" or "lychee" nuts. The shrivelled pulp around the dried seed is very pleasant in flavor and resin-like in texture. The fruit can also be preserved and canned in syrup or made into jelly[18] or sherbet and ice cream.[24]

B. Freezing of Lychees

The fresh flavor of lychee can be preserved in best manner by freezing, and the simplest method is to freeze the fruit without peeling. The fruit, in turn, may be peeled, seeded, or left unseeded and frozen in syrup. Peeling is usually done by hand, or by hot-lye dip and

Table 1
QUANTITATIVE DETERMINATION OF ORGANIC ACIDS IN LYCHEE[a]

Organic acid	Based on methyl ester data (meq/100 g)	Based on TMS[b] data (meq/100 g)
Malic	4.16	3.57
Citric	0.52	0.04
Succinic	0.04	0.25
Levulinic	0.01	trace
Phosphoric		0.2
Glutaric		0.04
Malonic	0.02	
Lactic	0.02	
Ascorbic[c]	0.28	0.28
Volatile acids[d]	0.13	0.13
Total	5.18	4.51
Titratable acids[d]	4.60	4.60

[a] Each value is the mean of 7 or more replicates.
[b] Separation of organic acids as derivatives of trimethylsylil as described by Chan et al.[8]
[c] Values obtained colorimetrically.
[d] Values obtained titrimetrically.

From Chan, H. J., Jr. and Kwok, S. O. M., *J. Food Science*, 39, 792, 1974 (Copyright by Institute of Food Technologists). With permission.

mechanically.[7] Lychees are sometimes fermented for Chinese medicine or used to make wine.[15]

C. Storage of Fresh Lychees

The shelf life of fresh unpackaged lychee at room temperature is less than 72 hours.[19] Desiccation occurs during transport with accompanied loss of red shell color and development of browning, most probably due to an aerobic oxidation polyphenolase system.[2] The pericarp did not darken when lychees were placed under high vacuum or in ascorbic acid solutions. Darkening also failed to occur when heated pericarp was exposed to air. Browning of lychees was reduced considerably by refrigerated storage in polythene bags.[2,4] Storage up to 5 weeks was possible at 2°C. Macfie[19] reported that a chlorine sanitizing treatment followed by packaging in polyethylene film and storage at 10°C controlled decay of lychees during storage, extending the shelf life of fruits.

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Chapter 12

TAMARIND

I. INTRODUCTION

The tamarind is a leguminous pod, driest of all fruits, most acidic and the one with the highest sugar content. Tamarind is most probably native to tropical East Africa.[6] It was introduced into India long ago, where it was readily adopted and cultivated. The Egyptians and Greeks of the 4th century B.C. were well acquainted with the tamarind. Among the many names for the tamarind, the most common ones in the literature are: ''tamarin'', ''tamarindier'', ''tamarindo'', and ''imli''. Tamarind grows in tropical countries of both hemispheres and has been naturalized in the subtropics. It is cultivated in parts of Florida, but does not grow and fruit well in California. The early work on various aspects of tamarind, such as history, uses, chemistry, technology, etc., have been reviewed by Morton,[22] Lewis and Neelakantan,[19] Lefevre,[17] Hasan and Ijaz,[9] Fisch,[8] and more recently by Bueso.[6]

A. Botany

The tamarind *(Tamarindus indica* L.) belongs to the *Leguminoceae,* the third largest family, including annual and perennial herbs, vines, shrubs, and trees. It is a large, evergreen tree with a graceful foliage. It can grow to heights of 30 m, but most often it attains heights of only about 10 m. The tree grows slowly, taking 10 to 12 years before it matures and can yield fruits; it can live up to 200 years. The alternate leaves contain many small leaflets which fold at night; leaves are about 1.2 to 2.5 cm long. The five-petaled flowers grown in terminal recemes are yellow with red lines and about 2.5 cm wide. The abundant fruit is an irregularly-shaped pod measuring about 2.5 to 17.5 cm in length and 2.5 cm in breadth. The pods produced by one tree vary greatly in size and shape, and may contain 1 to 10 seeds. The pulp and seeds are kept together by a few strands of strong fiber. The shiny red-brown seeds are hard, flat, and relatively square, measuring about 1.25 cm long and 0.4 cm thick. The pods are indehiscent.[6]

B. Cultivars

Two major types of tamarind cultivars are ''sweet-fruited'' and ''acid-flavored'' lines. The individual cultivars vary in fruit size, degree of tartness. The varietal characteristics of tamarind lines introduced from the Philippines are being evaluated at the U.S. Department of Agriculture Subtropical Horticulture Research Station at Miami, Florida.[13]

C. Production and Distribution

India is a major producer of tamarinds in the world with an estimated production of 250 thousand metric tonnes per year.[19] In Puerto Rico, there is no commercial production of tamarind, but the fruits grow wild throughout the island and in home gardens. The estimated production of tamarind in Puerto Rico during 1977 was about 23 metric tonnes.[6]

II. PHYSIOLOGY AND BIOCHEMISTRY

The tamarind fruit is composed of about 30% pulp, 40% seeds and 30% shells.[4] The tamarind has the lowest water content and, probably as a consequence of this, it has one of the highest levels of protein, carbohydrates, and minerals of any fruit. The soluble solids content of tamarind varied from 54° to 69.9° Brix.[3,4] Bueso[6] reported the following proximate composition of ripe tamarind pulp, compiled from the reports of Leung and Flores,[18] Wenkam and Miller,[30] and Hasan and Ijaz;[9] the data are reproduced in Table 1.

Table 1
PROXIMATE COMPOSITION AND FOOD ENERGY VALUE OF RIPE TAMARIND PULP

Constituent (%)	Leung and Flores[18]	Wenkam and Miller[30]	Hasan and Ijaz[9]
Water	22.60	33.89	62.50—69.20
Protein	3.10	3.28	1.40—3.30
Lipids	0.40	0.50	0.71—0.81
Carbohydrates[a]	71.80	59.76	—
Total sugars	—	—	21.40—30.85
Fiber	3.00	1.79	—
Cellulose	—	—	1.80—3.20
Pentoses	—	—	4.20—4.80
Total acidity[b]	—	—	17.10—18.40
Free tartaric acid	—	—	8.40—12.40
Ash	2.10	2.57	1.16—1.72
Energy (kcal/100 g)	272.00	230.00	—

[a] Determined by difference.
[b] Determined as tartaric acid.

From Bueso, C. E., in *Tropical and Subtropical Fruits*, Nagy, S. and Shaw, P. E., Eds., AVI Publishing, Westport, Conn., 1980, 375. With permission.

The total sugar content of tamarind was the second highest among fruits, equaled only by semidry dates, which have a total sugar content of about 61% fresh weight.[31] Baragano de Mosqueda[3] reported that the total sugar and reducing sugar contents of tamarind were 31.01% and 23.05%, respectively, on a fresh weight basis. Benero et al.[4] determined 40% of reducing sugars in the tamarind pulp. The other carbohydrates and related substances that make up fiber (cellulose, pentosans) were also present at high levels.[6]

The most outstanding characteristic of the tamarind is that its total acidity as tartaric acid ranges from 12.2 to 23.8%, which is uncommon in many plant tissues.[29] Although tartaric acid occurs in grapes, raspberries, grapefruit, and avocados, it is not present in such high proportion as in the tamarind. Lewis and Neelakantan[19] reported that about one half of the tartaric acid was present as potassium bitartarate (cream of tartar) and to a lesser extent as calcium tartarate. According to Lewis et al.,[21] tartaric acid was present at all stages of fruit development as an optically active (+) isomer. Malic acid, about 1.37 mg/mℓ,[11] existed as the (−) form, the most commonly found isomer in fruits.[29] The ascorbic acid content of tamarind was extremely low and varied from 2 to 20 mg/100 g.[17] The only other organic acid reported in tamarind fruit was oxalic acid.[26]

The tartaric acid is synthesized in the tamarind leaves in the light, and from leaves it is translocated to the flowers and the fruits.[21,24] The tartaric acid content of the leaves and fruit showed a seasonal variation.[6] As the fruit developed, the acid content of the sap decreased. During ripening of the tamarind pod, there was no decrease in the acid content, indicating that tartaric acid was not utilized during the fruit development. During this time, reducing sugars, however, accumulated to a large extent (40%), giving this sour fruit a sweeter taste. Patnaik[24] stated that the tartaric acid in mature fruits decreased as a result of setting up of the seeds.

About 55% of the total nitrogen in the tamarind pulp was non-protein N or soluble in 10% trichloroacetic acid,[15] and 70% of this N was contributed by free amino acids. The following amino acids were identified in the tamarind pulp: proline, pipecolinic acid, serine, beta-alanine, phenylalanine, and leucine. Lakshminarayan Rao[15] reported that higher levels

of these amino acids were present in ripe fruit than in immature fruit, indicating accumulation of free amino acids during maturation and ripening of tamarind.

The tamarind pulp is also unique in its high mineral content, as well as the highest phosphorus and calcium levels, and it is a fair source of iron. Tamarind excels in its riboflavin content and is also a good source of thiamin and niacin; however, it is poor in vitamin A and ascorbic acid.[18,30] Lee et al.[16] reported that the most abundant volatile constituent of tamarind was 2-acetyl-furan; coupled with traces of furfural and 5-methylfurfural, it formed the total aroma of tamarind. Tamarind fruit contains a variety of pigments: the anthocyanin chrisanthemin and a leuco-anthocyanidin predominate.[19] While leaves are rich in anthoxanthin, the fruits are poor in this pigment. The flower color is mainly due to xanthophylls.[20]

III. POSTHARVEST LOSSES

The ripe fruit is highly susceptible to mold and insect and bird attacks. During storage the dry, dark brown pulp may become soft, sticky, and almost black in color. The changes in texture are due to the hygroscopic nature of the pulp which contains high levels of sugar and acid, and presumably because of action of pectin enzymes. Lewis and Neelakantan[19] postulated that the pulp darkening in storage may be the result of nonenzymatic browning, since high amounts of free amino acids and reducing sugars are present in the pulp.

There are no serious diseases of tamarind. The bacterial leaf spot caused by *Xanthomonas tamarindi* was reported by Cook.[7]

IV. LOSS REDUCTION BIOTECHNOLOGY

A. Harvesting, Handling, and Maturity

The tamarind bears one crop per year, yielding about 200 kg per tree. In tropical North and South America, ripe fruits are available from April to June, while in India the harvesting season is from April to June.[6] The tamarind fruits should be left to ripen on the tree before harvesting. If not picked, the fruits may remain hanging for almost one year after flowering. The dry, ripe pods are easily cracked and the pulp and fibers are separated from the broken shells. After removing the pulp from the seeds, shell, and fiber, it is compressed and packed in palm leaf mats, baskets, corn husks, or plastic bags for storage and marketing. Tamarind pulp pressed into large cakes is sold as a valued food in Asian countries.

B. Utilization and Processing of Tamarind

1. Utilization

The tamarind tree is one of best tropical ornamentals, often planted for its beauty and to provide shade. Every part of the tree, viz., wood, bark, fibers, leaves, and fruit have been utilized in a number of ways. The medicinal value of the tamarind appears in the ancient Sanskrit literature. The antiscorbutic and laxative actions of the pulp and the diuretic properties of the leaf sap have been confirmed by modern medical science,[19] and several medicinal properties are claimed for preparations containing tamarind pulp, flowers, leaves, etc.[6]

As a food, the young seedling and tender leaves and flowers of mature trees are consumed by man as vegetables in salads, soups, and curries. Tender immature pods are used as seasoning for cooked rice, fish, and meats. The pulp of mature, ripe fruit is an agricultural product of considerable economic value in many parts of the tropical world. It is an important ingredient in such well-known products as worcestershire and barbecue sauces, and a fruit base in the preparations of jams, jellies, sherbets, ice creams, and a number of beverages, including carbonated drinks.[6] In north and south tropical American countries, tamarind pulp is most often enjoyed in the form of refreshing drinks and beverages. It is in this area that modern food technology has greatly advanced the methods for preservation and utilization of the tamarind fruit.

Tamarind seeds, a by-product of the commercial utilization of the fruit, are used as a food only to a limited extent.[10] The products from the seeds, however, have many other industrial applications, the most important one being in the manufacture of sizing powders.[15] Yoshida et al.[32] reported that tamarind seed polysaccharides form a jelly with any kind of sugar without the addition of acid. The chemical composition and structure of seed polysaccharides have been reported.[14,27] The properties and composition of tamarind seed oil[7] and fatty acids of tamarind gums[2] also have been studied.

2. Processing

Bueso[6] described the extraction of tamarind pulp and preparation of tamarind syrup, clarified tamarind juice, and other drinks. The pulping operation consists of breaking and removal of shells by hand, followed by agitation of the seeds in water to disperse the pulp and separate it from the seeds. Taber[28] prepared tamarind syrup in the following manner: The pulp was separated from the seeds by covering with water, placing in a steam bath for several hours, allowing to stand overnight, filtering through a linen filter, and washing with hot water. The industrial method used in India for the manufacture of tamarind juice concentrate is also based on the extraction of all solubles from the fruit pulp with boiling water.[23] Baragano de Mosqueda[3] included a prefermentation period of the pulp in a 1:2 (fruit:flower) dilution prior to pulping, and heat treatment while extracting the tamarind pulp with water. The fruit pulp was soaked for 24, 48, and 72 hours in order to develop aroma and flavor characteristics, to soften the tissues, and to facilitate the extraction process. Benero et al.[4] developed a method for mechanically extracting the tamarind pulp from unpeeled fruit. The pulp was removed from the broken shells and seeds after dilution with water. The fruit pulp was diluted with water in the proportion of 1:2 and 1:5. These dilutions produced slurries which allowed continuous operation of the pulping line. The 1:2 dilution produced the highest soluble and total solid yields with excellent fruit flavor, pulps giving about 13.2° Brix. Kanakku[12] described extraction of the sour principle from tamarind fruit by warm-water extraction of the fruit, followed by filtration and clarification of the filtrate by bleaching with SO_2 (Indian patent, 1323). A commercial production of tamarind juice concentrate has started in Mysore (India), based on a technology developed by scientists at CFTRI, Mysore.[1]

The recommended concentration of tamarind pulp in a syrup is between 20 and 24%, so as to produce a beverage with distinctive flavor and desirable acidity.[28] Such syrup contains 56.7% total solids, 43.8% reducing sugars, 56.5% total sugars, and a total acidity of 1.11% as tartaric acid. Tamarind juice concentrate is prepared in India by clarification of the fruit extract, concentration of the clear extract under vacuum to about 65 to 68% total soluble solids, and filled hot into sterile glass containers.[23] This product sets to a jam-like consistency upon cooling.

A clarified tamarind juice is one in which the structural and colloidal phases are removed to avoid sedimentation. Baragano de Mosqueda[3] developed a process of clarifying tamarind juice by treatment with 0.12 to 0.15% gelatin. After agitation of the fruit pulp with gelatin, the mash is left standing for 10 to 15 days at 6° to 10°C. The colloidal particles precipitated during this period are removed by decantation. The juice is then filtered in a vacuum, using asbestos. The fruit mash is adjusted to 0.75 to 0.80% tartaric acid content and 18° Brix, and pasteurized for 5 min at 80° to 85°C. The juice maintains its distinctive color and flavor and is absolutely transparent.[6] Scientists working at CFTRI, Mysore, India, developed a simple and easy-to-operate process to make dehydrated tamarind powder, packed in high-density polyethylene pouches.[1]

Benero et al.[4] prepared a tamarind and a tamarind-soursop soft drink of great acceptance. The tamarind drink contained 9 to 12% pulp and was adjusted to 21.5° Brix. The drinks thus prepared were pasteurized at 85°C, canned in plain tin containers, cooled, dried, and stored at 29.4°C. After one year of storage, the drinks were found acceptable by a taste panel.

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Chapter 13

ACEROLA

I. INTRODUCTION

The acerola or West Indian cherry originated in tropical America and is cultivated mainly in the West Indies and northern parts of South America. It is nutritionally rich, having a very high ascorbic acid content.

A. Botany

Britton and Wilson[9] referred to acerola as *Malpighia glabra* L. According to Knight,[17] the true taxonomic identity of acerola is not resolved presently. The genetic material collected in Puerto Rico was classified as *Malpighia punicifolia* L.; that from Cuba, Florida, Central America, and other areas was classified as *M. glabra* L. The fruits of *M. mexicana* A. Juss *(M. edulis* D. Smith), which has large edible fruit, differ from the true West Indian cherry in having permanently pubescent leaves. They are called ''acerola'' in Mexico and Central America. In Puerto Rico, the West Indian cherry is referred to as *M. punicifolia* L. and also as *M. glabra* L.[4] These two names are synonymous but apply to a species very different from the West Indian cherry. The correct name of the West Indian cherry is *Malpighia emarginata* DC. According to Asenjo[4] the name *M. glabra* is applicable to a species unknown in Puerto Rico, which is native to Jamaica, Mexico, Central America, and northern parts of South America. Acerola adapts favorably to the warm and humid climate of the tropics and subtropics.

B. Cultivars

The ''B-17'' was the most important commercial cultivar of acerola selected in Puerto Rico, which has been surpassed by ''B-15'' in yield and vitamin C content. Other cultivars grown in Puerto Rico are ''A-14'', ''A-12'', ''B-6'', ''B-7'', and ''B-8''. The pulp and juice of the ''Florida Sweet'' cultivar are low in acidity and are most suitable for fresh consumption. The performance of the ''B-17'' clone of acerola was studied by Singh-Dhaliwal and Torres-Sepulveda.[29]

C. Production and Distribution

The acerola is widely distributed throughout tropical America, Africa, and the West Indies. It has also been introduced in Hawaii and India. Production records of 163 individual West Indian cherry trees belonging to 10 selected clones have been reported.[16]

II. PHYSIOLOGY AND BIOCHEMISTRY

The acerola has been studied for its synthesis and retention of ascorbic acid. Nakasone et al.[22] reported that ascorbic content reached a peak between the 16th and 18th day after inflorescence; the quantity of vitamin C exceeded 4% and then declined to concentrations lower than those found on the 12th day after anthesis. Del Campillo and Asenjo[11] confirmed these results in Puerto Rico and further observed that fruits from trees grown on their own roots were only slightly lower in ascorbic acid content than the fruits from the grafted plants. The acerola fruits of plants grown in direct sunlight had the highest content of ascorbic acid which decreased with declining amounts of sunlight. The exposure of harvested acerola fruits to direct sunlight, however, significantly decreased their ascorbic acid. The field-stored fruits lost small amounts of ascorbic acid content if shade was provided. The ascorbic acid content was occasionally found to increase with freezer storage.[22]

Table 1
PROXIMATE ANALYSIS AND VITAMIN C CONTENT OF WEST INDIAN CHERRIES

Constituents	Acerola juice[12]	Pitted fruit[20]	Edible portion[20]
Protein (N × 6.25)[a]	0.39	0.39	0.68
Moisture[a]	94.15	92.28	91.10
Ash[a]	0.21	0.20	0.45
Fat[a]	0.28	0.34	0.19
Crude fiber[a]	0.26	0.43	0.60
Carbohydrate by difference[a]	4.71	6.36	6.98
pH	3.5	3.6	—
Ascorbic acid reduced[b]	1455.8	1496.4	2329.00
Dehydroascorbic acid[b]	38.2	196.4	—
Total vitamin C[b]	1494.0	1692.8	—

[a] Percent.
[b] mg Percent.

Table 2
VITAMINS OF B GROUP IN WEST INDIAN CHERRIES

Vitamins	Juice[1-3,7] (μg%)	Juice[12] (μg%)	Pitted fruits[12] (μg%)	Edible portion[20] (μg%)
Thiamin	24	30.0	30.0	28
Riboflavin	73	50.0	50.0	79
Niacin	480	290.0	407.0	340
Vitamin B_6	205	4.4	8.7	—

The proximate analysis and vitamin C content of acerola have been studied extensively.[12,20] Asenjo[4] has summarized the recent work. The proximate analysis and vitamin C content of West Indian cherries as reported by these workers is given in Table 1. Table 2 lists the important vitamins of the B group.[1-3,7,12,20] The West Indian cherry from Puerto Rico contained 0.61 mg of beta-carotene per 100 g of juice, which is equivalent to 1017 IU of vitamin A per 100 g of juice.[4] Floch[14] reported that French Guyana acerolas contained 1.099 mg of beta-carotene per 100 g ripe fruit, equivalent to 1832 IU of vitamin A. The workers from Brazil reported a very high amount of beta-carotene in ripe and fully ripe acerola fruits, 590 and 1026 mg/100 g, respectively.[15] Leme, et al.[18] subsequently reported that fully ripe fresh fruits from 2 different batches contained 0.59 and 0.2 mg/100 g of beta-carotene. Miller et al.[20] obtained beta-carotene values of 0.408 mg/100 g of edible portion for the Hawaiian West Indian cherry. Asenjo[4] concluded that acerola is a good source of provitamin A.

In addition to ascorbic acid, acerola also contains other organic acids. The titratable acidity (mℓ of 0.1 N NaOH/100 mℓ juice) of ripe fruits varied from 81.6 to 188.5 mℓ and in partly ripe fruit from 133.8 to 208.4 mℓ. The acidity of juice varied in proportion to its ascorbic acid content but not linearly,[4] probably due to the presence of other acids, particularly l-malic acid (25 to 50% of total acids). Asenjo and Moscoso[6] observed that the acerola juice of partly ripe fruit ranged from 2.3 to 3.7 (average 3.2) mg of reducing sugars per 100 mℓ. The corresponding values for ripe fruit were 3.0 to 5.4 (range) and 4.1 (average). Santini[26] reported that the acerola clones did not differ significantly in values of reducing sugars (3.7 to 3.9 mg/100 mℓ). The qualitative chromatographic studies carried out by Santini and Huyke[27] indicated the presence of glucose, fructose, and sucrose in the fresh juice of the West Indian cherry.

Table 3
MINERALOGICAL COMPOSITION OF ACEROLA

Minerals	Juice[12]	Pitted fruit[12]	Pitted fruit[10]	Edible portion[20]
Calcium[a]	9.9	11.7		8.7
Phosphorus[a]	8.8	10.9		16.2
Total iron[a]	0.54	0.24		0.17
Lead[a]	31.0	120.0		
Arsenic acid[a]	10	10		
Sodium[a]	3.2	2.7	14[b]	
Fluoride[a]	14.0	10.0		
Potassium[a]			83[c]	

[a] mg/100 g.
[b] (Range 11 to 16.)
[c] (Range 46 to 116.)

The mineralogical composition of the edible portion, juice, and pitted fruit as reported by different workers is given in Table 3. The West Indian cherries are not a significant source of calcium, phosphorus, and iron when compared with the U.S. recommended dietary allowances.

The presence of ascorbic acid oxidase in the acerola has been demonstrated.[8] The ascorbic acid oxidase activity was rapidly lost when the fruit was stored, even under low temperature conditions. The fresh ripe fruit had more enzyme activity than the green fruit, which explains why the ascorbic acid content of the ripe fruit is much lower than that of the green one. The ascorbic acid from acerola had earlier been isolated in the crystalline form by Asenjo and Freire de Guzman,[5] precipitated in the form of lead salt by adding neutral lead acetate. Santini and Nevarez[28] also crystallized ascorbic acid from West Indian cherry juice using a modified procedure developed by the U.S. Department of Agriculture. The average recovery was 77.4% (range 60.0 to 96.0%).

III. LOSS REDUCTION BIOTECHNOLOGY

A. Harvesting, Handling, and Maturity

Fully mature but firm acerola fruits are harvested for processing and canning. Since the picking of the fruit from trees is difficult due to the prickly nature of the trees, the harvesting can be speeded up by keeping the center clear by pruning. Hand-picking is time-consuming and involves excessive labor costs. Mechanical harvesting using automated shakers is practical. The fruit are picked every alternate day or at least after every 3 days during the harvest period.[30]

The acerola fruits are harvested when they are beginning to turn pinkish orange or light red. The experiments conducted on maturity indices of acerola at the Isabela Agricultural Experiment Station, using the "B-17" cultivar, indicated that the total solids were much higher, but the ascorbic acid content was much lower at the end of the season. The highly significant correlation was obtained between total solids and ascorbic acid content of ripe acerola fruits,[19] suggesting that these characters are influenced by maturity and ripeness. Pantastico et al.[23] stated that no standardized tests are available to establish harvest maturity of acerola cherries. Criteria such as color, flavor, and sweetness are, however, used occasionally to judge the optimum stage of fruit ripeness. The fruit to be sent to distant markets is generally harvested at a greener stage than the one used for local markets and immediate processing.

B. Low-Temperature Storage

Pantastico et al.[24] recommended temperature of 0°C and 85 to 90% relative humidity to extend the storage life of acerola fruit for about 8 weeks, with 6.3% average loss of weight. In Puerto Rico, the West Indian cherry is exported in a frozen state to the continental U.S., where it is used after processing. The loss of ascorbic acid in canned acerola juice could be minimized by holding it at 7°C.[25]

C. Processing of Acerola

Acerola fruit can be processed into a number of stable products such as juice, powder, jelly, and puree. The juice and dehydrated West Indian cherry powder have been used extensively to enrich other fruit juices with ascorbic acid.

1. Juice

The juice is generally squeezed in a cider press. Fully mature, firm fruits give a higher yield of juice. The juice thus obtained is clarified by centrifugation followed by filtration. Employing "Hyflo Super Cel"®, Sanchez-Nieva[25] canned the juice after pasteurization. The flash pasteurization of the juice is a tubular heat exchanger at 88°C for 45 sec caused only a slight loss of ascorbic acid (less than 2%). When the juice was stored in plain tin or sanitized enameled containers and stored at room temperature (27 to 29°C), the loss of ascorbic acid during 1 year varied from 53.5 to 81.5%. About 4 to 10% of the original ascorbic acid was lost in less than a 1-month period, during which the cans usually showed swelling. The loss of ascorbic acid in cans stored at 7°C was 21% during 1 year. No significant changes were observed in reducing sugars, total acidity, or pH under either conditions of storage, i.e. at room temperature or at 7°C.

Fitting and Miller[13] investigated the effects of freezing and heat treatments on retention of ascorbic acid in acerola juices stored with or without sugar. The frozen juice was stored in plastic bags, and the bottled juice was boiled for 3 min and bottled in sterile conditions. These bottles were stored at room temperature and away from the light. Fitting and Miller[13] found that all the frozen acerola juices, whether hot-pressed or cold-pressed and whether from ripe or half-ripe fruits, retained about 82 to 87% of the original ascorbic acid during the 8 months of storage as compared to 60% for the bottled product. Dilution of juice with water and addition of sugar had no beneficial effects on stability of ascorbic acid in the frozen product. The flavor of acerola juice has been reported to be affected by heating and canning. Sanchez-Nieva[25] found that the pleasant flavor of freshly extracted juice was altered to a hay-like flavor by heating. The change, however, did not prevent the use of the juice as a source of ascorbic acid and fortifying agent. Fitting and Miller[13] observed that fortification of the frozen juices of pineapple, passion fruit, and guava with that of ripe and half-ripe acerola fruits had little effect on flavor and color of the juice during 8 months of storage.

2. Powder

Industrial production of dehydrated West Indian cherry powder in Puerto Rico has overcome the problem of evolution of CO_2 by the pasteurized canned acerola juice or concentrate. The juice can be freeze-dried to less than 1% moisture to make it extremely stable. The dehydrated powder is, however, very hygroscopic. A high-vacuum belt-dryer with a cold- and a hot-drum has been developed for this purpose. A film of about 0.03 cm-thick acerola concentrate is applied to the belt head by electrical radiant elements. After the initial drying, the belt is passed over the heated drum at about 82°C. Subsequently the belt and the juice are allowed to cool before passing over the cooled drum, at −7°C and 2 mm absolute pressure. The dehydrated juice is scraped off into alternate vacuum chambers. The vacuum is broken and the product is removed in a room at ambient temperature with relative humidity of 5 to 12%. The dehydrated juice thus obtained is pale pink to light tan in color, and contains less than 10% moisture and 18 to 28% vitamin C.[4]

Leme et al.[18] studied the stability of ascorbic acid and beta-carotene during dehydration of acerola pulp by freeze-drying and subsequent storage. The losses of ascorbic acid during processing ranged from 3.6 to 6.4%. The losses of vitamin C per month were between 0.9 and 1.1% when the dehydrated product was stored at room temperature for 4 to 9 months. There were no losses of beta-carotene during the dehydration process, but the mean monthly losses ranged from 1.9 to 3.0%. The dehydrated product on an average contained 11.0% ascorbic acid and 5.0% beta-carotene.

3. Jelly

The preliminary investigation by Mustard[21] indicated that the ascorbic acid content of acerola jelly ranged from 499 to 763 (average 600) mg/100 g jelly. A small amount of lime juice was used to replace commercial pectin in the preparation of acerola jelly, since acerola is low in its pectin content. A good quality jelly can be prepared using a mixture of equal parts of green and ripe acerola fruits having high ascorbic acid, well above 1000 mg/100 g jelly. However, losses in the vitamin C content of jellies can be as high as 50% during a storage period of 6 months.

4. Puree

Acerola puree is made from freshly picked ripe fruits. The washed whole fruits are blended to uniform consistency in a grinder. The resulting puree is pressed through several plies of cheese cloth to remove the seed debris. It is then mixed with half its weight of granulated sugar and some citrus pectin for the desired consistency. After blending, the product is packaged in moisture-proof containers and frozen. Acerola puree can be used to prepare delicious punches for topping and flavoring ice cream.[4]

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Chapter 14

NUT CROPS

I. CASHEW

A. Introduction

The cashew is one of the most nutritious food crops of the tropical world, with its high protein and fat content. It has appreciable amounts of minerals (calcium, phosphorus, and iron) and vitamins compared to other nuts such as almonds, walnuts, and peanuts.

1. Botany

The cashew *(Anacardium occidentale* L.) belongs to the family *Anacardiaceae*, which includes many economically important tropical and subtropical trees and shrubs. The cashew is native to south-eastern Brazil and is widely distributed throughout the tropical world from the American seacoast to the West Indies. Its growth is favored by a mild tropical climate, and the crop is susceptible to freezing temperatures. The cashew can be grown at elevations as high as 1000 meters, but it does best below 500 meters.[4] It was introduced in India in the early 16th century. The native Tapi Indians of Brazil called it by the name ''A caju''. The Portuguese dropped the letter ''A'' to call it by the name ''Caju''. The cashew is known as ''Caju'' in several languages. The fruit consists of the swollen fleshy pedicel and an exposed seed. The pedicel is juicy, astringent, nutritious, and is characterized by a pleasant flavor. It is rich in ascorbic acid, sugars, and vitamins. The seed is the source of cashew nuts used in confectionery and desserts.[18] According to Shivashankar et al.[21] cashew apple is not a true fruit but a swollen penduncle to which the cashew nut is attached. It is a soft but fibrous, juicy fruit possessing exotic flavor. Based on external color of the fruit, the cashew apple can be broadly classified into two types: Red and Yellow.

The hard, kidney-shaped nut of the cashew forms the raw material for the processing industry. The nut consists of a tough, fibrous shell (pericarp), a thin, brown, filmy skin (husk or testa), and white kernel as an edible part. The cashew apple (peduncle) can be utilized to prepare a variety of edible products after removing the astringent, acrid principle present in the apple. The shell has a honeycombed structure, and its cells contain a natural secretion of corrosive fluid known as cashew nut shell liquid (CNSL), which is a valuable raw material for a number of polymer-based industries.[21]

2. Cultivars

Cashew, being a cross-pollinated crop, has led to large variations in the seedling progenies. The yield performance studies carried out at the All India Coordinated Cashewnut Improvement Project showed that progenies of ''Vridhachalam'' types such as M 10/4, M 6/1, M 14/3, and M 76/1, and one type of Anakkayam, LA 139, were the higher yielders (over 10 kg per tree). The size and quality of apple were also good.

Vengurla-1 and Vengurla-2 are the two outstanding selections made by the Konkan Agricultural University, Dapoli, in Maharashtra (India). The vegetatively propagated trees of these cultivars have yielded 20 and 28 kg of nuts per tree at the age of 20 years, for Vengurla-1 and Vengurla-2, respectively. The breeding program undertaken at different Cashewnut Research Stations in India have resulted in high-yielding hybrids such as ''Hybrid-5'', ''Hybrid-11'', ''Hybrid-19'', ''Hybrid-24'', ''Hybrid-25'', ''Hybrid-26'', ''Hybrid-74'', ''Hybrid-92'', ''H-3-19'', ''H-3-17'', ''H-3-12'', ''H-3-7'', ''H-2/11'', and ''H-2/12''.[21]

Table 1
MAJOR PRODUCERS OF CASHEW NUTS, CHESTNUTS, AND WALNUTS[3]

Countries	1969—71	1978	1979	1980
		Cashew Nuts		
India	175,667	150,000	150,000	160,000
Mozambique	180,067	61,000	66,000	71,000
Brazil	24,118	77,000	80,000	65,000
Tanzania	108,382	68,478	57,128	46,000
Kenya	162,000	36,000	20,000	20,000
World	**519,464**	**408,911**	**389,636**	**379,275**
		Chestnuts		
China	144,667	168,000	170,000	180,000
Italy	66,871	73,111	70,849	68,000
Japan	48,933	60,600	61,000	63,700
Turkey	47,167	45,000	46,000	55,000
France	52,570	43,710	53,342	47,700
Korea Rep.	2,285	29,494	41,000	41,200
World	**520,348**	**501,801**	**547,830**	**539,480**
		Walnuts		
U.S.	106,957	145,149	188,693	179,622
Turkey	99,008	130,000	145,000	130,000
China	94,667	115,000	118,000	122,000
U.S.S.R.	31,233	52,500	55,000	58,000
Italy	82,333	46,600	44,870	50,000
Spain	33,967	30,428	32,000	32,000
World	**686,006**	**737,570**	**795,512**	**781,807**

Note: Production in metric tonnes.

3. Production and Distribution

The cashew leads all other tree nuts with its world production of 450,000 metric tonnes (MT). It ranks third (20% of the market) in the international trade of nut crops after hazelnut (29%) and almond (21%). The world production of cashew nuts decreased from 519,464 MT in 1969-71 to 379,275 MT in 1980. India is the largest producer of cashew nut producting (more than 40% of the world cashew nuts). The other major producers of cashew nuts are Mozambique, Brazil, Tanzania, and Kenya (Table 1). The production of the African countries has significantly decreased during the last decade.[3]

B. Physiology and Biochemistry

The proximate chemical composition, amino acid composition of cashew nut protein (kernel globulins), and the physico-chemical characteristics of the kernel fat are given in Tables 2, 3, and 4, respectively. Kuppuswamy et al.[7] reported that the cashew kernel is rich in protein and fat and has fair amounts of essential amino acids. The cashew nut fat has a high proportion of unsaturated fatty acids (81.8%) and oleic acid (73.8%) (Table 4). Iyengar and Kale[5] reported that the cashew nut kernel contained 47.0% fat, 21.2% protein, and 22.3% carbohydrate, as well as useful amounts of calcium, phosphorus, and iron and vitamin B_1, niacin and riboflavin. The fresh cashew apples contain about 11% sugar, a pleasant amount of acid, and about 185 mg of ascorbic acid per 100 g.[22]

Table 2
PROXIMATE COMPOSITION OF CASHEW KERNEL[1]

Constituents	Percentage
Moisture	5.9
Carbohydrates	22.0
Protein	21.0
Fat	47.0
Minerals	
Calcium	0.05
Phosphorus	0.45
Iron	0.005

Table 3
AMINO ACID COMPOSITION OF CASHEW KERNEL GLOBULINS[7]

Amino acid	Percentage
Arginine	10.3
Histidine	1.8
Lysine	3.3
Tyrosine	3.2
Cystine	1.0
Phenylalanine	4.4
Methionine	1.3
Threonine	2.8
Valine	4.5

Table 4
PHYSICO-CHEMICAL CHARACTERISTICS OF CASHEW NUT FAT[1]

Particulars	Percentage
Fatty acids	
Saturated	18.20
Unsaturated	81.80
Oleic acid	73.80
Linoleic acid	7.70
Palmitic acid	6.70
Stearic acid	11.44
Unsaponifiable matter	0.42
Specific gravity at 15°C	0.9155 — 0.9180
Acid value	2.2 — 8.2
Saponification value	180.0 — 190.6

The cashew nut kernel contains appreciable amounts of calcium, phosphorus, and iron. The husk of the cashew nut has about 24 to 26% tannins, 52 to 57% fiber, and 3 to 5% oil.[21]

The cashew nut shell liquid consists chiefly of two reactive phenolic compounds: anacardic acid (90%) and cardol (10%). Anacardic acid is decarboxylated by heat during the roasting

process, yielding cardanol. Cardol is a resorcinol derivative having a long unsaturated hydrocarbon chain.

C. Postharvest Losses

Stem borer, tea mosquito, leaf miner, and thrips are important insect-pests of cashew nut. Though cashew is comparatively free from serious diseases, dieback and anthracnose sometimes cause heavy losses of cashew nuts.

D. Loss Reduction Biotechnology

1. Harvesting, Handling, and Maturity

Cashew apple is ripe when the basic color of the outer skin turns yellow or yellowish red. The greenish color of immature nuts turns gray-brown when mature. The harvesting is done by picking the fruit from the trees or collecting the fallen fruits from the ground. Particular care must be exercised to collect apples at the right stage of maturity when they are used for liquor (fenni) making. The harvesting extends over a period of 8 to 12 weeks. The nuts are dried in the sun for about a week before storage.

The commercial harvests of cashew nut starts from the 5th or 6th year of planting. The economic life of a cashew tree is about 40 years.

2. Low-Temperature Storage

Pantastico et al.[14] recommended a temperature of 0 to 1.7°C with 85 to 90% relative humidity. Under these conditions, the cashew nuts can be stored for up to 5 weeks.

3. Processing of Cashew Nuts

Shivashankar et al.[21] described a number of products of the cashew nut fruit: liquor, vinegar, juice, jam, and candied products. The quality of processed products of the cashew apple is greatly influenced by the amount of astringent and acrid principles. The tannin content of juice extracted from cashew nut fruits of different locations differs significantly. The major polyphenolic constituent of cashew apple juice is leuco-delphinidin. The juice can be blended with juices of other fruits such as lime (1.5%) and pineapple (50%) to yield satisfactory drinks. The pasteurized juices stored in cans or bottles at 26.7°C can stand in good condition for 32 weeks. For candying, ripe cashew fruits have been found to be superior to less-ripe fruits. The ascorbic acid content of the fruit is lost almost completely, and only a trace amount of tannins are retained, when the fruits are steamed for 10 min at 10 psi.[18]

Shivashankar et al.[21] defined the processing of cashew nuts as the recovery of the edible meat portion of the kernal from nuts by manual or mechanical means. It consists of moisture conditioning, roasting, shelling, drying, peeling, grading, and conditioning of kernels, and packaging. Highly mechanised plants are presently available for cashew processing.

4. Utilization of Cashew Nuts

Cashew nuts have been utilized in many ways. Cashew nut shell liquid is an important by-product of the cashew processing industry. It is separated from the shells during roasting of cashew nuts in the oil-bath process. It is also produced by the solvent-extraction process. It is utilized in the preparation of resins, after removing metallic impurities and traces of sulfurous compounds. The cashew nut shell liquid easily lends itself to polymerization, forming resins which are used as starting materials for anti-corrosive paints and varnishes. These varnishes are used for producing electrical insulators, water proofing paper, and cardboard finishing agents. Rubbery gels (used as cementing materials) and cation polymers are also prepared from the cashew nut shell liquid.

Nanjudaswami et al.[12] reported that the astringent and acrid principles of the cashew apple can be removed by simple methods, in order to use the fruits in several ways. Juices,

beverages, concentrates, preserves, jam, pickle, chutney, and candied products can be made from the fruits.

a. Cashew Apple Beverages

1. **Clarified juice.** It is advantageous to promptly process the highly perishable cashew apple. "Clarified juice" can be prepared by extracting juice from sound and healthy fruits in a screw-type juice extractor. The astringent and acrid principles are removed by gelatin treatment (0.5%). After settling and filtration, the brix of the juice is raised to 15°, and acidity is adjusted to 0.4% by addition of sugar and citric acid. The juice thus prepared is bottled after pasteurization.
2. **Cloudy juice.** Cashew apples steamed at 2 to 4 kg pressure for 5 to 10 min or boiled for 4 to 5 min in 2% salt solution, followed by cooling and washing in water, are generally used for juice extraction. The juice expressed is further treated with 0.045% gelatin. After the separation of precipitate, the juice is preserved like clarified juice.
3. **Blended juice.** Cashew apple juice can be blended with juices of other fruits like grape, apple, lime, and pineapple; better preparation results especially by blending with pineapple and lime juices.
4. **Cashew apple juice concentrate.** A good quality concentrate can be prepared using clarified cashew apple juice in a forced circulation evaporator with added SO_2.[16] It is not advantageous to concentrate juice beyond 60° brix. The beverage prepared from concentrate appears to be more acceptable due to mellowing of the flavor.[12]
5. **Cashew apple vinegar.** Satyavati et al.[20] reported the possibility of preparing vinegar from cashew apple juice after raising the brix to 12°. Addition of 0.05% ammonium phosphate facilitated the fermentation process. The cashew vinegar thus made with 5.3% acidity compared well with the commercial preparations.
6. **Cashew apple candy and jam.** Shivashankar et al.[21] described the method of preparing candy from cashew apple after curing the ripe fruit in brine solution starting with 2% concentration and increasing it up to 10% within 5 to 6 days and steaming at 2 to 4 kg pressure for 10 to 15 min. This was followed by actual preparation of candies, starting with a 30 brix syrup containing 0.05% citric acid.

   These authors also described the preparation of cashew apple and mixed jam after curing the fruit as detailed above. Sugar equal to the weight of fresh fruit is used and, 0.3% citric acid is added toward the end of the cooking process. Mixed fruit jam is made by mixing the cashew apple pulp with an equal quantity of banana or pineapple pulp. Johnson[6] reported that the following 5 types of preserves or candies are marketed in Brazil: stewed apples in syrup *(doce om calda);* typical sweet, thick jam *(doce);* cooked pulp formed into balls and coated with sugar *(caju cristalizado),* and cooked and partially dried apples in syrup *(caju ameica).*

b. Canning of Cashew Apple

Firm ripe fruits are lye-peeled by cooking in a boiling 0.5% sodium hydroxide solution for 3 to 4 min and in a boiling solution of 0.2 N sulfuric acid for 1 min. The fruits, after washing, are steamed for 4 min at 2 kg pressure, followed by cooling in water. The cut fruits are then poured into cans, covered with 40° brix syrup, exhausted, and processed for 30 min at 4 kg pressure, before cooling in water.

c. Cashew Apple Chutney and Pickles

Cashew apple chutney is prepared from fruits treated with 2% brine, followed by washing and steaming at 4 kg steam pressure for 5 to 7 min. The raw green fruits thus treated are washed and kept in 10% brine for a week, and then pickled after trimming off the undesirable end portion.

d. Alcoholic Beverages

These are prepared by fermenting cashew apple juice. In the Goa region of India, an alcoholic preparation called "fenni" is made by fermenting the juice and distillation by the old method.[13] Shivashankar et al.[21] stated that recently, modern methods of distillation are being adopted. These authors described the method of preparation of cashew nut "fenni": The juice is extracted and collected in vats. It is acted upon by microorganisms present in the apple to cause fermentation. The fermented juice is distilled in pot stills to give "arrack", which on further distillation produces "fenni". The product is further matured to give "fineness". The scientists working at the Central Food Technological Research Institute, Mysore (India) have developed a method to prepare a good-quality dessert wine and brandy from cashew apple. The distillation is done using column stills. About 74 liters of brandy is yielded from one metric tonne of fruit by this method.

In Tanzania a product called "Koniogi", akin to gin, is made. A bottled cashew apple in sugarcane brandy is sold in Brazil. While the peduncle is still small, the nut is removed and the peduncle is introduced into the bottle and allowed to grow. When fully matured the apple is separated from the main branch and the bottle is filled with sugarcane brandy.[6]

e. Cashew Apple Residue

Cashew apple residue left after juice extraction (about 30 to 40%) can be utilized to recover low methoxyl pectin (LMP), or as a cattle feed after drying. The peduncles are dried and used as bait for catching crustaceans in Brazil and as animal feed in Mozambique.

II. CHESTNUT

A. Introduction

The European species of chestnuts *(Castanea sativa)* are the commercially most important, although they are also grown in China *(C. mollissima)*, Japan *(C. crenata)*, and the U.S. *(C. dentata)*. The native chestnuts grown in the north and central Atlantic states of the U.S. were wiped out by diseases.[19]

Unlike other nuts, the chestnut is a starchy nut with only about 5% oil on fresh weight basis. High-quality chestnuts should be bright, shiny, and free from mold with plump and fresh kernels. Chinese chestnuts have light-brown shells, and European and Japanese species are dark brown.

The world production of chestnuts increased from 520,348 in 1969-71 to 539,480 metric tonnes in 1980. The major producing countries during 1980 were China (producing about 1/3 of world chestnuts), Italy, Japan, Turkey, France, and the Korean Republic (see Table 1).

B. Postharvest Losses

Chestnuts are very susceptible to molds. Infection may occur while the nuts are still on the tree. Wright[27] isolated fungi of several (12) genera from Chinese chestnuts. He also found that some kernel decays were associated with bacteria and yeasts.

C. Loss Reduction Biotechnology

1. Harvesting, Handling, and Maturity

Chestnuts are picked up every day or on alternate days during the harvest season to avoid mold infection. Prompt removal of fruit from the ground is necessary.

2. Low-Temperature Storage

Prompt storage of chestnuts at 0°C has been recommended. Ryall and Pentzer[19] pointed out that prevention of moisture loss from kernels and reduction of decay organisms are the

principal objects of storage of chestnuts. The burial of sacks of nuts in moist sand or earth in shade has also been used. Woodroff[25] recommended storage of chestnuts at 0° to 2.2°C immediately after harvest.

3. Packaging of Chestnuts

The use of vented polyethylene bags prevents moisture loss. Lipovec[8] compared the storage life of European chestnuts with or without polyethylene box liners at −1.2° to 0°C, and in a cellar with temperature decreasing during the storage period from 12.8° to 3.9°C. Lipovec found that the nuts stored in unlined boxes at either cellar or cold-storage temperatures lost so much moisture that the kernels turned hard and "bony". The beneficial effects of packaging were attributed to the accumulation of a suitable concentration of CO_2 in the polythene lined boxes, but no CO_2 figures were given to substantiate this.

III. WALNUT

A. Introduction

The Persian (English) walnut *(Juglans regia)* probably originated in the region of the Caspian Sea, but it is grown all over Mediterranean Europe and most other temperate zones of the world. Southern Europe and western U.S. are the principal producers of the walnuts. Black walnut, native to eastern North America, is called *J. nigra*. The western walnut, *J. californica,* is of little commercial interest.[19]

The world production of walnuts increased from 686,006 metric tonnes in 1969-71 to 781,807 metric tonnes in 1980. The principal walnut-producing countries in 1980 were the U.S., Turkey, China, USSR, Italy, and Spain (Table 1).

B. Postharvest Losses

High-oil nuts may develop rancidity during storage if they are not dried and packaged properly.

C. Loss Reduction Biotechnology

1. Harvesting, Handling, and Maturity

Mechanical harvesters are employed to harvest walnuts when matured. Present methods of harvest involve mechanical trunk or limb shakers, windrow machines to concentrate nuts between rows, and pick-up machines to gather the windrowed crop. Smooth ground or spreading of canvas sheets is essential.[19] In some orchards with younger trees, the shake-catch method with essentially the same equipment as for prune harvest is used. Martin[10] recommended spray-applications of 500 to 1000 ppm of ethephon (2-Chloroethylphosphonic acid), 2 to 4 weeks before harvest to aid mechanical harvest. The hulls dehisced readily and a single mechanical shaking removed the nuts completely, about 3 weeks earlier than normal harvest periods. The quality of the harvested nuts was superior to those of untreated walnuts.

2. Low-Temperature Storage

The properly dried in-shell walnuts can be held to remain in good marketable condition if stored at 0°C with 60 to 75% relative humidity. Shelling reduces the storage life of nuts by about one-half, as is the case with most other high-oil nuts. Prompt storage at low temperature is, therefore, recommended for in-shell nuts and is most essential for the shelled walnuts. The in-shell walnuts can be sored for about 6 months or less if stored at 10°C.[19] Lutz and Hardenburg[9] reported the effects of various temperatures on storage behavior of Persian and black walnuts (Table 5). While Persian walnuts can be stored for about one year at 0°C, the storage life of black walnuts can be extended up to 15 months by storing them at 0°C.

Table 5
STORAGE LIFE OF NUTS AT DIFFERENT TEMPERATURES[9]

Storage temp. (°C)	Approximate storage life in months				
	Almond	Chestnut	Pistachio	Walnut (Persian)	Walnut (black)
0	15 — 20	4 — 6	—	10 — 12	—
10	6 — 12	—	—	6 — 12	—
21.1	6	—	—	2 — 4	—
0	6 — 12	—	24	6 — 12	15
10	6	—	15	6	8
21.1	6	—	15	1	8

3. Controlled-Atmosphere (CA) Storage

Wright[26] studied the effects of temperature, CO_2 and N_2 on shelled nuts as compared with air storage. The vacuum-packed walnut kernels kept better than those packed in any other way. In vacuum, the walnuts remained in good quality up to 19 to 25 months of storage at 0° and 10°C. Even at 21.1°C, the vacuum-packed nuts remained in good condition for up to 19 months. Storage in atmospheres of CO_2 or N_2 was found to be better than the air storage at each temperature but was much less effective than the vacuum storage.

4. Irradiation

Exposure of shelled walnuts to gamma irradiation, even at the relatively low dosage of 50,000 reps, seriously damaged flavor and odor. Objectionable changes occurred immediately after exposure which did not disappear after 30 days of holding. Ryall and Pentzer[19] concluded that irradiation is not feasible to control molds in shelled nuts.

5. Chemical Control of Losses

Various anti-oxidant chemicals have been used to control rancidity in shelled walnuts during storage and marketing. Wells and Barber[24] reported that walnuts in packages labeled as "antioxidant treated" in the retail stores were much superior to the untreated; about 95% of the nuts from these packages were rated good to excellent in flavor, odor and color. This study pointed out the significance of protecting shelled nuts during unfavorable temperatures and intense light exposure in the retail stores. Musco and Cruess[11] reported the effects of light, antioxidants, and vacuum packing on walnut meats. The deterioration, as formation of fatty acids, was found to be closely related to the moisture content and exposure to oxygen and light. Packing of the nuts in light-proof films and in vacuum and low moisture content slowed deterioration. Studies with commercial and laboratory-formulated antioxidants[17,23] confirmed the usefulness of antioxidants in preserving superior quality of the nuts.

IV. ALMOND

A. Introduction

The sweet almond *(Amygdalus communis)* has been cultivated from ancient times, and it originated in Mediterranean basin.

One race of the almond which produces bitter nuts, is grown in some parts of Europe, largely for the manufacture of flavoring extracts. The soft-shelled cultivars are commercially more important than the hard-shelled ones.

The world production of almonds increased from 600,918 metric tonnes in 1969-71 to 864,987 metic tonnes in 1980. The principal commercial producers during 1980 were the U.S., Spain, Italy, Iran, Tunisia, and Turkey (Table 6).

Table 6
MAJOR PRODUCERS OF ALMONDS AND PISTACHIOS[3]

Country	1969—71	1978	1979	1980
		Almonds		
U.S.	114,910	129,455	275,511	245,664
Spain	138,400	306,700	197,500	221,000
Italy	185,800	179,400	97,550	140,000
Iran	33,667	50,000	50,000	50,000
Tunisia	9,867	35,000	30,000	37,000
Turkey	19,333	26,000	26,000	30,000
World	**600,918**	**869,887**	**804,887**	**864,987**
		Pistachios		
Iran	17,900	60,000	20,000	40,000
U.S.	—	1,179	7,802	12,338
Turkey	9,167	6,300	20,000	10,000
Greece	1,109	1,487	2,213	2,073
Italy	2,200	500	500	500
World	**32,379**	**76,371**	**45,551**	**69,961**

Note: Production in metric tonnes.

B. Postharvest Losses

Deterioration of almonds during storage largely consists of darkening of the kernels and loss of typical almond flavor. The dark and stale almonds after prolonged storage may develop rancidity, particularly the shelled kernels.

C. Loss Reduction Biotechnology

1. Harvesting, Handling, and Maturity

Almonds are harvested manually or mechanically. Before mechanization, hand-held mallets were used to strike the major limbs for removing nuts. Canvas sheets, either manually moved or dragged from tree to tree by tractor power, are used to catch the falling nuts.[19] Most commercial almond orchards presently employ inertia limb shakers to remove nuts, windrowers to concentrate them, and pick-up machines to gather the nuts. The shake-catch systems are preferred to avoid contact of nuts with toxic molds producing aflatoxins.

2. Low-Temperature Storage

In-shell almonds can be stored for about 7 to 8 months at room temperature below 70% relative humidity, if the nuts are dried properly. For prolonged storage, in-shell almonds should be held at 10°C or below. Almonds can remain in excellent marketable condition for as long as 2 years if stored at 0°C with about 75% relative humidity.[19]

Although shelling generally increases perishability of all nuts, the shelled almonds are comparatively less perishable than most of the other nuts. Air storage at 0°C with 60 to 75% relative humidity is satisfactory to hold almonds for 15 to 16 months (Table 5).

3. Controlled-Atmosphere (CA) Storage

Wright[26] reported that modified atmosphere (vacuum, CO_2 or N_2) at 0°C was superior to air for maintenance of flavor during prolonged storage. However, at 21.1°C, vacuum-packed almonds were superior in color to those stored in CO_2, N_2, or air after 16 months of storage. Good quality was maintained for 8 months in vacuum, CO_2 or N_2, at 26.7°C, whereas those stored in air at this temperature turned black during 8 months.

V. PISTACHIO

A. Introduction

Pistachio nut *(Pistacio vera)* is native to semi-desert areas and mountains of south central Asia. It has been used as a nutritious food item since prehistoric times.

The commercial production of pistachio is concentrated in Turkey, Iran, Italy, Syria, and Afghanistan. The world production of pistachio more than doubled since 1969-71 (32,379 metric tonnes) to 1980 (69,961 metric tonnes). Table 6 lists the major producers of pistachios during this period.[3]

B. Loss Reduction Biotechnology

1. Drying

The moisture content of pistachio kernels at harvest time may be as high as 45%. This must be reduced to 4 to 5% within a few days of harvest. Natural air-drying can be employed in low-humidity and high-temperature conditions. The nuts can, however, be dried by forcing heated air at 35.0° to 37.8°C, very effectively and rapidly.[19] Bloch and Brekke[2] reported that in-shell pistachios could be dried from 22 to 30% to 5 to 6% moisture content within 12 hr with heated air at 35° to 37.8°C. The freshly harvested nuts with 45% moisture required about 18 hr in the dryer to reach 5 to 6% moisture.

2. Storage

Wells and Barber[24] observed that freshly harvested dried and shelled pistachios were very stable in storage. Nuts with 4.5% moisture and 49.2% oil were stored at 0°, 3.3°, 10.0°, and 23.8°C, and in N_2 at 3.3° and 23.9°C. After 60 weeks storage there was no rancidity, and a significant difference in quality between those held at 0° and 23.9°C. After 20 months storage, all samples were found to be in good condition. Lutz and Hardenburg[9] also reported that the storage life of pistachios can be extended up to 2 years by holding the nuts at 0°C (Table 5).

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Chapter 15

PERSIMMON

I. INTRODUCTION

The persimmon, or Kaki, belongs to genus *Díospyros* of the family *Ebenaceae*. Out of many important species of *Diospyros*, only four species are of commercial interest: *D. kaki* L., *D. lotus* L., *D. virgiana* L., and *D. oleifera* Cheng. *Diospyros kaki* is known as Japanese persimmon and is the most important species. It probably originated in China rather than Japan.[12] The persimmon has spread all over Asia and South America.

A. Botany

Ito[a] grouped kaki cultivars into two groups: (1) those which show no change in color of the flesh under the influence of pollination, and (2) those in which the fruit is darkened as a result of pollination; he referred to them as ''pollination constant'' and ''pollination variant'', respectively. ''Nonastringent'' and ''astringent'' are the two major groups of persimmons; each can be subdivided into two further groups based on whether they belong to ''pollination constant'' or ''pollination variant'' groups. Mori[14] thus classified Japanese persimmon cultivars into four groups as follows:

1. Nonastringent and pollination constant (PCNA) cultivars; e.g., ''Fuyu'', ''Jiro'', ''Gosho'', and ''Suruga'', (these usually have dark tannin spots).
2. Nonastringent and pollination variant (PVNA) cultivars; e.g., ''Zenjimaru'', ''Shogatsu'', ''Mizushima'', and ''Amahyakume'' (these have dark tannin spots and may become astringent when seedless)
3. Astringent and pollination constant (PCA) cultivars; e.g., ''Yokono'', ''Yotsumizo'', ''Shakokushi'', ''Hagakushi'', ''Hachiya'', and ''Gionbo'' (have no dark tannin spots)
4. Astringent and pollination variant (PVA) cultivars; e.g., ''Aizumishirazu'', ''Emon'', ''Koshuhyakume'', and ''Hiratanenashi'' (these are astringent when pollinated with some dark tannin spots around the seeds)

Nonastringent cultivars predominate in Japan, occupying about more than 60% of the total yield. While the nonastringent persimmons can be consumed as dessert fruit, astringent ones become edible only after removal of astringency or after drying.

B. Cultivars

''Fuyu'' is the most popular nonastringent cultivar of persimmon, grown over 80% of the cultivated area occupied by the sweet cultivars. Other important cultivars are ''Jiro'' (excellent quality and fine texture), ''Gosho'' (best quality of all cultivars, fine texture, and excellent, sweet taste), and ''Suruga'' (a new, high-yielding cultivar). In the astringent group, the most important cultivars are ''Hiratanenashi'', ''Hachiya'', ''Aizumishirazu'', ''Yotsumizo'', and ''Yokono''[9].

C. Production

Japan is the largest producer of persimmons, with its average production of 292,000 metric tonnes annually from 1973 to 1976. The production of persimmon in the U.S. has increased from 907.2 in 1959 to 2722 metric tonnes in 1974.[22] Other persimmon-producing countries are Brazil, Israel, Queensland in Australia, and India where the persimmon has been introduced.

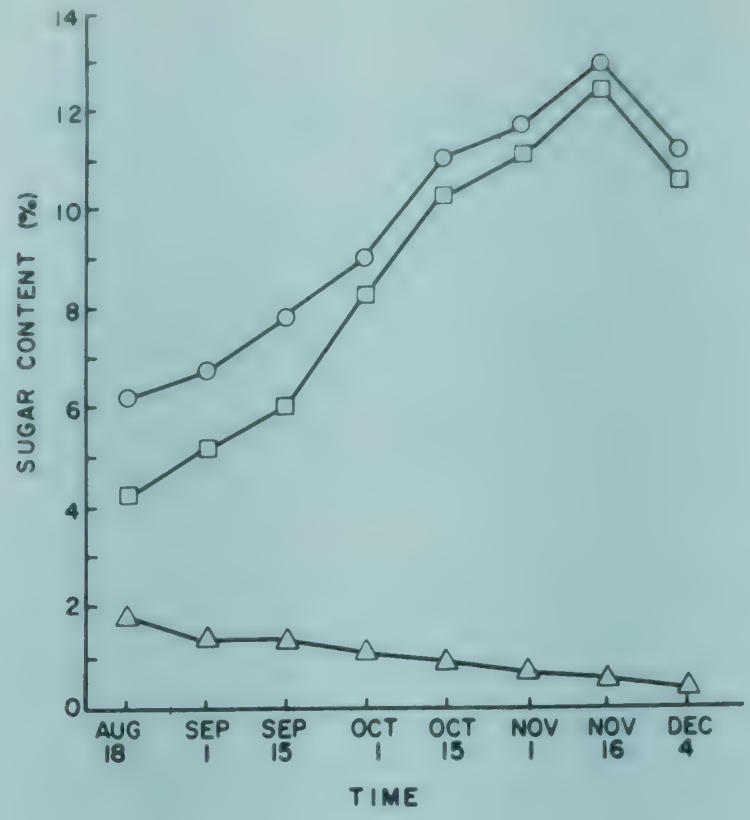

FIGURE 1. Changes in sugars during development of persimmon fruit (cultivar "Fuyu"). ○: total sugars; □: reducing sugars; △: nonreducing sugar. (From Kitahara, M., Takeuchi, Y., and Matsui, M., *J. Jpn. Soc. Food Nutr.*, 4, 138, 1951. With permission.)

II. PHYSIOLOGY AND BIOCHEMISTRY

A. Growth and Development

Water, sugars, pectins, tannins, carotenoids, and ascorbic acid are the main constituents of persimmon fruit. The reducing sugar content increases steadily during fruit development, reaching a maximum at the middle of November (Figure 1). Most of the sucrose translocated from leaves was hydrolyzed enzymatically to reducing sugars in the fruit flesh.[11] Other major changes taking place are in the pectin and tannin contents of the fruit. Mature fruits contained pectic substances varying from 0.52 to 1.07% in the four non-astringent cultivars,[7] predominating in water-soluble (64 to 69%) pectins. The tannin content of immature persimmon fruits is very high, which contributes to its remarkable astringency. The fall in the tannin content of fruits during growth and maturation of astringent persimmon cultivars is most striking,[9] reflecting the astringency of the developing fruit. The absolute content of soluble tannin per fruit reaches a maximum value in middle October and decreases thereafter.

The astringency of persimmon fruits can be removed by treatments with warm water, alcohol, or carbon dioxide.[9] The fruits treated with CO_2 gas remain firm and keep their quality after removal of astringency. A normal pressure method with a polyethylene bag cover (2.5 mm thick) is commonly used. It requires 3 to 4 days under a normal pressure at 20°C. Ito[9] quoted the work of Matsuo et al.[13] describing the new "constant temperature short duration" (CTSD) method. The treatment with CO_2 at 20°C for 18 to 25 hr, followed by storage in air at 30°C for 3 days, produced de-astringent fruit of excellent quality without abnormal softening. Gazit and Adato[5] recognized that there are two distinct processes in disappearance of astringency by the CTSD method: (1) an induction process in which exposure of the fruit to CO_2 gas causes chemical reactions related to occurrence of de-astringency (formation of an "astringency-removing factor"), and (2) a de-astringency

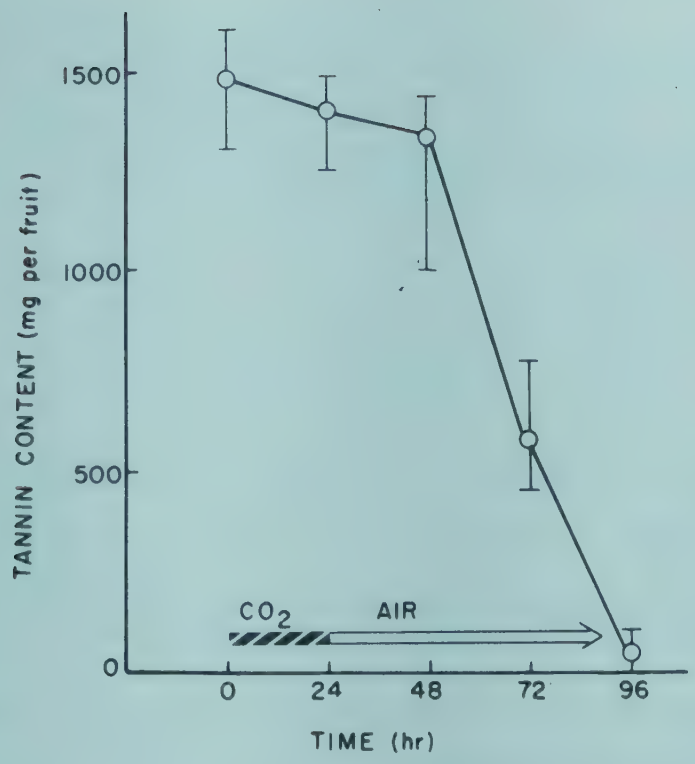

FIGURE 2. Changes in tannin content of persimmon *(kaki)* fruit during the disappearance of astringency by CO_2 treatment. (From Matsuo, T., Shinohara, J., and Ito, S., *Agric. Biol. Chem.*, 40, 215, 1976. With permission.)

process, in which the astringency of the fruit disappears gradually, and the presence of CO_2 is no longer essential. Figure 2 shows the change of tannin content during the disappearance of astringency by the CTSD-CO_2 method. Matsuo et al.[13] found that the tannin content of "kaki" fruit did not decrease significantly within the first 24 hr after the treatment, but it decreased rapidly during the subsequent 24 to 48 hr when exposed to air (Figure 2).

The color of persimmon fruit varies from red to yellow orange, primarily due to its content of carotenoid pigments. Brossard and MacKinney[1] surveyed pigments in 38 cultivars of *D. kaki* and two cultivars of *D. lotus*. The cryptoxanthin was the major component (30 to 40% of the total carotenoid content).

The ascorbic acid content of the peel and flesh of mature persimmon fruits of different cultivars is given in Table 1. The persimmon is a good source of ascorbic acid. The immature fruit and the nonedible peel of the mature fruit contain considerably higher amounts of vitamin C than the pulp of mature fruit.

B. Ripening and Senescence

Ethylene stimulates fruit ripening, and treatment with CO_2 destroys astringency without softening the fruit.[4] Ito[8] reviewed biochemical changes occurring in the ripening persimmon fruit.

III. POSTHARVEST LOSSES

A. Physical Injury

Ripe persimmons are very soft and mushy and can be easily bruised. The thin peel can be easily damaged or ruptured by rough handling.

B. Physiological Disorders

According to Kitagawa[10] persimmon fruits of both astringent and nonastringent cultivars

Table 1
ASCORBIC ACID CONTENT OF MATURE PERSIMMON FRUIT

Cultivar	Part of fruit	Ascorbic acid	Dehydro-ascorbic acid	Total ascorbic acid
Fuyu	Peel	195	25	220
	Flesh	41	11	52
Jiro	Peel	144	31	175
	Flesh	24	11	35
Okugosho	Peel	126	24	150
	Flesh	16	9	25
Hanagosho	Flesh	33	11	45
Seidoshi	Flesh	31	14	46

Note: mg/100 g fresh weight.

From Ito, S., in *Tropical and Subtropical Fruits*, Nagy, S. and Shaw, P. E., Eds., AVI Publishing, Westport, Conn. With permission.

develop brown flecks in their flesh. The tannin cells in these areas become coagulated and are shrunken and have brown protoplasts.

C. Diseases

Fruit rots, including blue mold rot, gray mold rot, and *Rhizopus* rot are common in the harvested fruits. Orchard diseases like anthracnose and *Phoma kikivora* cause spotting of the fruit.[17,21,23] Black spots occur during storage as the skin splits in the cuticle where fruit rots can gain entrance, especially for *Penicillium*.[18] Nizaradze and Lomsadze[15] reported that the astringent cultivars of persimmon were resistant to infections by *Penicillium* and *Botrytis* but not to *Rhizopus*. Ryall and Pentzer[18] concluded that careful handling of persimmons is essential to prevent peel breaks.

IV. LOSS REDUCTION BIOTECHNOLOGY

A. Harvesting, Handling, and Maturity

Persimmon fruits are picked when still firm enough to handle to avoid bruisings and injuries. The fruits are packed in one or two layers boxes lined with polystyrene films. Ryall and Pentzer[16] stated that nailed wooden boxes are generally used to ship persimmons in one-layer flats holding 10 to 12 lb of fruit. Two-layer lug boxes are used commonly for shipment. A few commercial shipments have been made using cartons and containers molded from polystyrene. Charney and Seelig[2] recommended that the fruit may be individually wrapped in paper to prevent abrasion injury.

B. Low-Temperature Storage

A temperature of −1.2°C and 90-95% relative humidity have been recommended for storing persimmons. Williams[20] reported that storage of persimmons at 0°C was better than 2.2° and 4.4°C, because it permitted less ripening. Ryall and Pentzer,[16] however, recommended −1.2°C to extend the storage life of persimmons up to 3 to 4 months. Persimmons in China are stored outdoors, about six fruits deep, on a bed of sorghum stems placed across trenches to give drainage and ventilation. The fruits are held under this condition from harvest until March. They are covered with a light reed-grass matting to protect them from rain. The frozen fruits are then covered with about 2 feet of dry grass to keep them frozen until spring.[3,19]

C. Controlled-Atmosphere (CA) Storage

A controlled atmosphere with 8% CO_2 and 3 to 5% O_2 at 1.1°C and 90 to 100% relative humidity was found to be optimum to store persimmons.[8] Storage of persimmons in sealed polyethylene bags (0.06 mm thick) at 0°C produced atmospheres of 5 to 8% O_2 and almost 100%, relative humidity, which improved the storage life of fruits.

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Chapter 16

DATE

I. INTRODUCTION

The date palm is native to the Mediterranean region and originated in the Persian Gulf area, where it is presently an important commercial crop.[23] Dates are nutritious food products with high amounts of sugars and small quantities of other nutrients. Except for the beta-carotene (vitamin A) content, they resemble most other dried fruits such as apricots and prunes.

A. Botany

The date palm *(Phoenix dactylifera* L.) belongs to the family *Palmaceae*. It is a dioecious plant with separate male and female trees, pollination usually occurring with the help of wind. However, in order to improve the fruit set, date palms are generally pollinated artificially by transferring pollen collected from male spadices onto female inflorescence. Since the pollen has a strong influence on the development, ripening, and quality of date fruits, it is often saved for a period of time and stored from season to season.[5] Bouguedoura[6] recently described the morphology and ontogenesis of growth from axillary buds of date palms. A vegetative or flower bud may arise from the primordium in the axil of a leaf or at the base of the date palm. A comprehensive study by Bouguedoura showed that both types of buds were the results of development from the some primordial structure. Vittoz[44] reported a survey of botany (pollination, cultivars), production, cultivation, pests and diseases, and economics of the date palm. The growth of the date palm is favored by long summers of dry hot climate.

B. Cultivars

Hundreds of date cultivars are known. The commercial production of dates in the U.S. is limited to four imported cultivars, including ''Deglet Noor'' which represents about 75% of the cultivated area. Another 10% is made up by three cultivars; i.e., ''Zahidi Khadrawy'', and Halawy (or Hallawi).[39] Knight[23] described several important cultivars of date palm grown commercially all over the world. ''Deglet Noor'' (Delgar Nur, or Daglat al-Nur), meaning ''date of the light'' or ''translucent seedling'', is valued for its large size, light color, delicate flavor, and excellent keeping qualities. It is high-bearing and ripens in October or early November. It requires a hot climate to ripen properly and needs protection from rain which sours the fruit. ''Zahidi'' (Zahdi) is a vigorously growing, hardy, and drought-resistant high yielder grown commercially in Baghdad and Iraq. ''Khadrawy'' (Khadrawi) is another with noncloying flavored fruits. ''Hallawi'', meaning ''sweet'', is the world's leading cultivar of great commercial value, although ''Sayer'' (Sayir) produces the greatest quantity of fruit annually. ''Hallawi'' is a light-colored soft-fruited date grown mainly in the Basra region of Iraq, and from there it is shipped. The fruits are extremely sweet, honey-like, but flavor is not rich. ''Sayer'' (or Sayir), meaning ''widespread'', is the commercial cultivar of the world, having the highest production, although its fruit quality is not very high. It tolerates adverse climatic conditions such as salinity. The medium to medium large sized fruits (3 to 4 cm long and 1.9 to 2.2 cm wide) are very sweet. The flavor is noncloying but not rich or in any way distinctive. ''Medjool'' (or Majhul), meaning ''unknown'', is the principal export quality date of Morocco. The fruits of this cultivar are rich in flavor with delicious taste.

Most of these cultivars have been introduced to the U.S. since 1900. Other cultivars of

date palm described by Popenoe[39] are "Dueiki" ("Duwaik" or "Duwaiki") grown in Egypt and Saudi Arabia, "Hayani" of Egypt and the Nile delta, "Kabkabe" (Kabkab) of southern Iran, "Khustawai" (Kustawy) of Iran and Baghdad, "Maktum" (Maktoom) of Iraq, and "Shalabi" (Shalibi) and "Sukkari" of Baghdad.

C. Production and Distribution

The date palm has been grown in northern parts of India and Africa and southern Spain from early times. The USDA introduced a number of improved cultivars from North Africa and the Persian Gulf region between 1900 and 1902. From Spain the date palm was taken to Mexico. It is widely grown in Brazil, most of the African countries, and throughout the Middle East and Asia.

The average production of date palm in the U.S. during the period from 1973 to 1977 was 21,409.8 metric tonnes.[40] No reliable data on world production of dates are available. Iraq is considered to be the leading date-producing country in the world, with its annual production estimated at about 350,000 metric tonnes. Other major producers are Iran, South Arabia, Quatar, Kuwait, Morocco. Sultanate of Oman, Mexico, Pakistan, Algeria, Brazil, Tunisia, UAR, U.S., and some African countries like Sudan.

II. PHYSIOLOGY AND BIOCHEMISTRY

Like most other dried fruits such as raisins, apricots, and prunes, date fruit is composed mainly of carbohydrates and small quantities of other nutrients (Table 1). The date carbohydrates consist largely of reducing sugars (glucose and fructose) and sucrose, the proportion of which varies greatly with cultivars and fruit maturity. Most of the available reports on fruit composition pertain to changes in total and invert sugars and to their ratios, as influenced by the variety and fruit maturity. The reducing sugars are commonly believed to occur in an equimolar proportion of glucose and fructose, arising from the inversion (hydrolysis) of sucrose. This is only approximately correct since Coggins et al.[8] reported that the ratio of fructose to glucose for "Deglet Noor" dates grown in California was 1.28. Hussein et al.[20] classified several Saudi Arabian cultivars of date into three broad categories based on their chemical composition: (1) the "soft" dates with more than 30% moisture, containing almost no sucrose, (2) the "semidry" types, containing 20 to 30% moisture and a high level of sucrose, including the principal cultivar of the U.S., i.e., the "Deglet Noor", and (3) "dry" dates with less than 20% moisture and containing approximately equimolar concentrations of sucrose and reducing sugars. According to Coggins and Knapp[7] within a given variety, the sucrose and reducing sugars are related to quality and texture of the fruit. Although the total sugars for the different grades were essentially the same when expressed as a percentage of dry weight, the better grades had higher amount of sugars per date. An early report by Vinson[42] stated that total sugars and sucrose contents increased with ripening. He noted the rapid accumulation of total sugars and inversion of sugars at the later stages of development.

In the soft and semidry varieties of Egyptian dates, the reducing sugars were to the extent of 30 to 40% of the dry weight, and sucrose was nearly absent during the early period of fruit development (green stage). Shortly before the dates started turning color, the reducing sugars and sucrose began to accumulate. The reducing sugars reached a maximum level of 50 to 60% of dry weight, as the dates started to turn color. The sucrose content also increased rapidly at this time. At the end of the turning phase, the concentration of reducing sugars began to drop, the total sugar concentration increased only slightly (about 80 to 90% of dry weight), and sucrose concentration increased but more slowly. At the fully colored stage, the concentration of both the reducing sugars and sucrose were about 35 to 40%. The sucrose content of soft varieties was completely hydrolyzed to reducing sugars during the curing stage.[30]

Table 1
NUTRITIONAL COMPOSITION OF DATES AND OTHER DRIED FRUITS

Proximate Composition (%)

Fruits	Water	Protein	Fat	Carbohydrates		Ash	Calories
				Total	Fiber		
Dates	22.5	2.2	0.5	72.9	2.3	1.9	274
Raisins	18.0	2.5	0.2	77.4	0.9	1.9	289
Apricots	25.0	5.0	0.5	66.5	3.0	3.0	260
Prunes	28.0	2.1	0.6	67.4	1.6	1.9	255

Minerals (mg)

Fruits	Calcium	Phosphorus	Iron	Sodium	Potassium
Dates	59	63	3.0	1	648
Raisins	62	101	3.5	27	763
Apricots	67	108	5.5	26	979
Prunes	51	79	3.9	8	694

Vitamins

Fruits	Vitamin A (I.U.)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Ascorbic acid (mg)
Dates	50	0.09	0.10	2.2	0
Raisins	20	0.11	0.08	0.5	1
Apricots	10,000	0.01	0.16	3.3	12
Prunes	1,600	0.09	0.17	1.6	3

From Watt, B. K. and Merrill, A. L.[45]

Yousif et al.[46] recently reported the nutritional composition of four Iraqi date cultivars with regard to their contents of sugar, protein, fat, ash, fiber, water-soluble vitamins, minerals, and trace elements (Table 2). The dates had low moisture, protein, fat, and nonreducing sugar contents, but they had relatively large amounts of reducing sugars. The ratio of glucose to fructose was a function of the agroclimatic conditions prevailing in the areas. The dates contained moderate amounts of thiamin, riboflavin, and folic acid; biotin and ascorbic acid were present in small quantities. With respect to minerals, the dates could be considered as a rich source of iron, potassium, copper, sulfur, and manganese and a fair source of calcium, chlorine, and magnesium (Table 2). El-Shurafa et al.[11] determined the organic and inorganic constituents in seeds (pits) of six leading cultivars of Libyan dates. The average of different constituents (on dry weight basis) of all cultivars was: starch 20.64%, reducing sugars 2.4%, nonreducing sugars 1.98%, protein 6.43%, oil 9.2%, ash 1.2%, Ca 0.038%, K 0.244%, P 0.112%, Na 0.008%, Cl 0.161%, Fe 30.4 ppm, Mn 15.7 ppm, Zn 28.84 ppm, and Cu 8.1 ppm. The iodine number, saponification value, and acid value of oil were 54.8, 207.3, and 1.75, respectively. The cultivars significantly differed in their contents of reducing sugars, starch, total carbohydrates, protein, oil, ash, K, P, Cl, Mn, and Zn.

Table 2
NUTRITIONAL COMPOSITION OF 4 COMMERCIAL CULTIVARS

Proximate Composition

Cultivars	Moisture	Total soluble solids	Total insoluble solids	Protein	Fat	Ash	Crude fiber	pH
Hallawi	7.30	84.20	17.90	2.30	0.51	1.92	1.82	5.60
Sayer	7.50	81.30	10.00	2.78	0.32	1.80	1.72	6.00
Khadrawi	9.50	80.80	9.52	2.43	0.47	2.12	2.28	6.70
Zahdi	8.26	82.14	9.23	2.16	0.43	1.86	2.50	6.10

Distribution of sugars

Cultivars	Total sugars	Reducing sugars	Sucrose	Glucose	Fructose	Glucose/fructose ratio
Hallawi	87.90	82.72	4.80	43.69	37.21	1.17
Sayer	86.10	82.60	3.50	44.79	38.04	1.17
Khadrawi	87.44	81.91	4.50	44.73	38.48	1.16
Zahdi	86.86	73.40	12.70	32.77	39.15	0.83

Vitamins (mg/100 g)

Cultivars	Thiamin (B_1)	Riboflavin (B_2)	Biotin (H)	Folic acid (Folacin)	Ascorbic acid (Vit. C)
Hallawi	99	173	4.63	57	3.56
Sayer	130	135	4.66	70	17.51
Khadrawi	94	149	4.09	43	3.20
Zahdi	80	167	5.74	63	2.41

Mineralogical Composition (macro elements, mg/100 g)

Cultivars	Calcium	Phosphorus	Potassium	Sulfur	Sodium	Chlorine	Magnesium
Hallawi	184	16	854	10	14	260	56
Sayer	203	3	833	20	10	312	58
Khadrawi	133	15	894	14	16	266	60
Zahdi	207	14	887	21	5	342	59

Mineralogical Composition (micro elements, mg/100 g)

Cultivars	Iron	Manganese	Copper	Zinc	Cobalt	Fluorine
Hallawi	5.26	5.86	2.77	1.39	0.76	0.20

Table 2 (continued)
NUTRITIONAL COMPOSITION OF 4 COMMERCIAL CULTIVARS

Mineralogical Composition (micro elements, mg/100 g)

Cultivars	Iron	Manganese	Copper	Zinc	Cobalt	Fluorine
Sayer	3.21	5.25	2.89	1.82	0.96	0.12
Khadrawi	4.50	5.14	2.54	1.29	0.96	0.14
Zahdi	10.37	5.16	2.75	0.74	0.95	0.12

From Yousif, A. K., Benjamin, N. D., Kado, A., Alddin, S. M., and Ali, S. M., *Date Palm J.*, 1(2), 285, 1982. With permission of the FAO Regional Project for Palm and Dates Research Centre in the Near East and North Africa, Baghdad.

The crude fiber content of the dates varies from about 2 to 4%. It is generally thought of as the insoluble, nonnutritive (undigestible) portion of a food, which includes pectin, lignin, hemicellulose, and cellulose. Vandercook et al.[41] stated that pectins play an important role in date texture by means of gel formation during curing. Coggins et al.[8] examined the inner and outer mesocarp of premium quality dates and commercially acceptable but low quality dates. Hussein et al.[20] determined the pectin content of some Saudi Arabian cultivars and classified them on the basis of their moisture content: the high-moisture (over 30%) cultivars had an average pectin content of 1.04% on a dry-weight basis while semidry (20 to 30% moisture) and dry (less than 20% moisture) cultivars had pectin contents of 1.75 and 1.51%, respectively. Rouhani and Bassiri[32] reported that the pectin content of immature green dates dropped steadily from 12.1% to a low value of 0.25% (dry weight) in ''Shahani''-grown dates. Haq and Gomes[12] isolated polysaccharides, using alcohol as an extracting agent. They extracted the residue further with cold and hot water, dilute acid, and aqueous alkali. The hydrolysis of dilute alkali-soluble polysaccharide gave a xylan having a 1,4-linkage. Coggins et al.[8] reported the lignin and cellulose contents of crude fiber, in ''Deglet Noor'' dates. The cellulose content of some Iranian dates varied from 4.43 to 6.48%.[10]

The dates contain about 1.5 to 2.0% proteins of high nutritive quality.[4] Hasegawa et al.[14] monitored changes in soluble and insoluble protein content during maturation and ripening of ''Deglet Noor'' dates. The soluble protein content increased steadily and reached its maximum level at the 50% soft stage, whereas the total protein content reached a maximum value of 127 mg per fruit at the early red stage.[41]

The crude fat content of date palm varies from 2.52 to 7.42%.[18] Kikuchi and Miki[21] investigated the lipids of Iraqi dates using a gas liquid chromatograph. Palmitic acid was present in the largest amount followed by capric and caprylic acids. These workers later identified cholesterol, stigmasterol, beta-sitosterol, and isofucosterol (using gas chromatography, mass-spectroscopy, and infrared spectroscopy).[22]

The organic acids of date palm affect its flavor and quality. Rygg[35] observed that high pH values were associated with high quality in ''Deglet Noor'' dates. He detected a distinct tartness in dates at the lower range of pH. The acidity of some Iranian dates varied from 2.53 to 4.43 meq/100 g.[10] Rygg[35a] reported that ''Deglet Noor'' dates with a low pH value had significantly more sulfur than high pH fruits. It has been observed that the pH increases and titratable acidity drops as the date fruits mature.[34] Rouhani and Bassiri[32] also found that the pH increased from 5.13 to 7.00, and the titratable acidity decreased from 7.7 to 1.4 meq/100 g dry weight, as the fruits matured.

The dates are not a rich source of vitamins. Vandercook et al.[41], however, stated that if the vitamin content is expressed in proportion to calories, dates contribute roughly their

share of the recommended vitamins. The recommended levels for thiamin, riboflavin, and nicotinic acid according to Pike and Brown[28] are 0.4, 0.6, and 6.6 mg/1000 calories, and the dates contained 0.32, 0.35, and 8.0 mg/1000 calories, respectively. The most abundant mineral in dates is potassium, followed by phosphorus and calcium (Table 2). The high proportion of potassium and low sodium content may be of significance to persons on low sodium diets. The iron content calculated on a caloric basis (1.1 mg/100 calories) contributes significantly to the daily requirements.[41] Rygg[38] reviewed the research work carried out in the seventies on the chemical composition of date fruit in the U.S.

The biochemical investigations and enzyme studies in the date have been limited to texture and color of the fruit, which are the important factors determining the fruit quality. Vandercook et al.[41] stated that invertase is the most important enzyme influencing the quality of dates. Hasegawa and Smolensky[15] followed changes in invertase activity of "Deglet Noor" dates during maturation and ripening. In immature fruit, substantial activity of the enzyme was found only in the insoluble form (5 units per fruit). Soluble invertase, which was virtually absent in the green stage, increased rapidly during the period when fruit matured from the green to the early red stage and reached its maximum level 10 units per fruit) at the late red stage. The activity decreased slightly as the maturity progressed, and the insoluble invertase appeared to be converted to soluble invertase. Hasegawa and Smolensky[15] noted that soft, good-quality dates (natural and waxy) had a higher activity of invertase than tough dates of low quality.

Softening of fruit during ripening is related to alterations in pectic substances through the action of two pectic enzymes, namely polygalacturonase and pectin methyl esterase. The presence of these enzymes has been reported in dates.[3,8,14] Hasegawa et al.[14] demonstrated a close relationship existing between polygalacturonase activity and fruit-softening as a function of maturity. Like invertase, polygalacturonase activity was much higher in soft (natural and waxy) dates than in the relatively tough dates. Al-Jasim and Al-Delaimy[3] monitored changes in the activity of pectin methyl esterase during maturation and ripening of 4 Iraqi cultivars of date. Unlike cellulase and polygalacturonase, pectin methyl esterase activity increased as the fruit grew, the greatest increase in enzyme activity occurring during the period between the yellow stage and the 50% soft stage. The activity reached its maximum level at the latter stage and then decreased slightly as the fruit ripened further. The presence of other enzymes like cellulase[16] and polyphenoloxidase[13] has been demonstrated.

Vandercook et al.[41] pointed out the dramatic relationship between the onset and development of hydrolytic enzymes and softening of dates during ripening. Maier and Metzler[25] observed the importance of sucrose hydrolysis on the textural quality of dates. These workers used the extent of invertase catalyzed sucrose hydrolysis as an index of hydrolytic enzyme activity.

Since the color of dates is primarily due to the pigments produced by browning reactions, the browning phenomenon is of interest to interpret the role played by each system of pigmentation during ripening, processing and storage. Vandercook et al.[41] described the following three systems of formation of brown pigments in dates: (1) sugar browning, (2) enzymic oxidative browning of polyphenols, and (3) oxidative browning of tannins.

In general, the browning reactions occur more rapidly at elevated temperatures than at low (refrigerator) temperatures.[27,36] The relative rates of browning in "Deglet Noor" dates differ widely at a given temperature. While at room temperature enzymic browning of polyphenols proceeds at an observable rate, sugar browning is much slower at low temperature. It predominates over oxidative browning of polyphenols and tannins, above 38°C. As the green "Deglet Noor" date matures, the concentration of polyphenols undergoing enzymic browning decreases, and the fruit turns light brown in color. However, as the fruit dries on the palm, the browning enzymes are probably inhibited by the low moisture content, so that the enzymic browning is slowed appreciably. Light or slightly greenish-colored fruit probably

dries to a low moisture content before sufficient enzymic browning can take place. After hydration and an intermediate storage, the fruit has a medium brown color. The substrates required for polyphenolic enzymes are not detectable during these periods.[26]

The browning reactions are much slower at very low moisture levels.[37] Vandercook et al.[41] mentioned that studies are presently being carried out on the control of native hydrolytic enzymes and possible application of appropriate outside enzymes during postharvest treatments to improve the quality of tough dry dates and sugar wall dates. Addition of invertase and cellulase have shown some promise.

III. POSTHARVEST LOSSES

Fusarium wilt (''Bayoud'' disease) caused by *Fusarium oxysporum* f. sp. *albedinis* is the most important disease of date palms in the world. Djerbi[9] recently reviewed the incidence of disease in North Africa, giving details of history, distribution, diagnosis, and control. All varieties of dry dates are commonly attacked by more than a dozen insect pests belonging to *Coleoptera* and *Lepidoptera* orders. By far the most serious insect species for stored dates in Iraq are the fig moth *Ephestia cautella* and the saw-toothed grain beetle *Oryzaephilus surinamensis*.[2,19] Hayes[17] stated that no serious diseases of date palm are known in India or Pakistan, but considerable damages are caused by insect pests, the most important being the larva of a weevil, *Rynchophorus ferrugineus*, and scale insects.

IV. LOSS REDUCTION BIOTECHNOLOGY

A. Harvesting, Handling, and Maturity

The date may be used long before it is fully ripe. The damages caused by rains may often be prevented by early harvesting.[17] The best cultivars may repay the additional cost of picking each fruit separately at its prime maturity but most dates are generally harvested by the bunch. High-quality fresh dates are plump, smooth, golden brown to almost black in color depending on cultivar, and free from dirt, mold, insects, and surface sugar crystals. They may be soft and syrupy or firm and dry, depending upon type and end use.[33] The fresh, fully ripe date is a choice dessert fruit and without cold storage will ferment within a few days. The great bulk of the crop is dried soon after its harvest, mainly in the sun.

The fact that total sugar content varies significantly with fruit maturity is an important consideration in terms of time of harvest. All other factors being equal, an early harvest will result in more immature dates with a lower sugar content than a late harvest. Vinson[43] stated that dates cannot be artificially ripened into an economic product before a certain minimum accumulation of sugar takes place.

B. Low-Temperature Storage and Heat Treatment

As a general rule, dates will retain their quality for a longer period of time when they are held under refrigerated (0°C) conditions than at ambient temperatures. Lutz and Hardenburg[24] recommended −17.9° to 0°C with 75% or less relative humidity to store dates for about 6 to 12 months.

Particular attention must be paid to the moisture level of the stored fruit to prevent microbial spoilage and chemical deterioration. A relatively small difference in moisture content profoundly affects the keeping quality of ''Deglet Noor'' dates. The fruits darken four times as rapidly at 23.9°C when stored at 24% moisture content than when stored at 20% moisture content. Such differences are less striking at lower temperatures.[37] Depending upon the variety and condition at the time of harvest, dates are normally given some type of treatment to dry or hydrate. Heat treatments are used most frequently. When ''Deglet Noor'' dates were heated to temperatures above 60°C, a reddish color developed and astringency and off-

flavors were detected. The undesirable red pigments and astringent compounds probably arose as breakdown products of the insoluble pro-cyanidin tannins.[41]

C. Irradiation

Ahmed et al.[1] recently reported studies on disinfection of commercially packed dates of the "Zahdi" cultivar by ionizing radiation or by methyl bromide fumigation. A complete disinfection was achieved in both methyl bromide and radiation-treated boxes when stored for 25 days. The live insects found in the irradiated dates were genetically sterile and developmentally inactive. On longer periods of storage (55 or 80 days), live, active, and fertile insects were found in the treated as well as untreated (control) boxes indicating reinfestation (Table 3).

D. Processing and Drying of Dates

Most of the dates produced in the world are dried in the sun to a moisture content of less than 20%. The dry dates can be held at room temperature for years without significant changes in their color and quality.

Dates are almost exclusively sun-dried under the natural climatic conditions of the areas in which they are grown. Rodriguez et al.[31] stated that only a small proportion of dates is dehydrated in Arizona and Southern California to process dates into bakery and confectionary products like candies. As the dates are harvested from the palm, they are usually astringent. To remove their astringency, dates are incubated at 32.2° to 37.8°C for a few days to ripen. The softened dates become translucent and their flavor improves. In the Middle East, dates are often allowed to ripen on the tree and are directly dried in the sun, after harvest.[31]

Table 3
INSECT DISINFESTATION[a]

Treatment	Storage period (days)	No. of lunch boxes examined[b]	Total no. of dates	Live insects per 100 dates
		Treatment 1		
Untreated (control)	25	8	273	7.7
Methyl bromide	25	8	256	0.0
Radiation	25	8	270	9.6 (sterile)
		Treatment 2		
Untreated (control)	55	8	240	65.0
Methyl bromide	55	8	258	7.8
Radiation	55	16	510	0.9
		Treatment 3		
Untreated (control)	80	2	65	73.38
Methyl bromide	80	8	241	1.6
Radiation	80	12	366	0.8

[a] Insect disinfestation of packed naturally infested dry dates (cultivar Zahdi) using methyl bromide or low dose of gamma radiation followed by different periods of storage

[b] For each treatment, two standard carbon boxes (48.5 × 31 × 19 cm) each holding 40 × 250 g lunch boxes were used.

Table 3 (continued)
INSECT DISINFESTATION[a]

From Ahmed, M. S. H., Al-Hakkak, Z. S., Ali, S. S., Kadhum, A. A., Hassan, I. A., Al-Maliky, S. K., and Hameed, A. A., *Date Palm J.*, 1(2), 249, 1982. With permission of the FAO Regional Project for Palm and Dates Research Centre in the Near East and North Africa, Baghdad.

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Chapter 17

LOQUAT, MANGOSTEEN, AND DURIAN

I. LOQUAT

A. Introduction

The loquat, Japanese plum, or medlar *(Eriobotrya japonica* Lindl.) belongs to the rose family, which includes several important fruit crops of the temperate region. The loquat is a subtropical fruit which probably originated in China.

1. Botany

The loquat is a small tree, rarely exceeding 10 m in height (average of 8 m). The fruits grow in loose clusters and are round, oval, or pyriform in shape, about 2.5 to 7.5 cm in length. The fruit has a tough skin and the flesh is firm, juicy, varying in color from white to deep orange. Cultivars with soft flesh are also known. Smooth, brown seeds (1 to 5) are generally found in each fruit.[18] The loquat adapts to a wide range of climate, from warm-temperate to tropics and subtropics.

2. Cultivars

The principal cultivars of loquat grown in Israel are ''AKKO 13'', occupying 60 to 70% area, ''AKKO 1'' (10 to 20% area), and ''Tsrifin 8'' and ''Tanaka'', each occupying about 10% of the planted area.[10] ''Tanaka'' originated in Japan, and the other three in Israel. ''AKKO 13'' is an early-season cultivar, ripening in March-April, with fruits having excellent storage properties (2 weeks at 0°C). The loquat cultivars grown in India are ''Golden Yellow'', ''Improved Golden Yellow'', ''Large Pale Yellow'', ''Large Agra'', ''California Advance'', and ''Tanaka''.[8] The cultivars recommended for California are ''Champagne'', ''Thales'', ''Advance'', ''Benlehr'', and ''Miller''. ''Fletcher'' and ''Wolfe'' are recommended for Florida.[10]

3. Production and Distribution

Japan is a leading producer of the loquat with its annual production of more than 22,000 metric tonnes. Israel is another major producer since 1960. India produces about 5000 metric tonnes annually.[8]

The loquat is widely distributed and is presently grown in Israel, India, the Mediterranean region, Madagascar, and parts Oceania, South Africa, Australia, North and South America, Argentina, Chile, and California and Florida.

B. Physiology and Biochemistry

The loquat fruit consists of about 60 to 70% pulp (wet weight), 15 to 18% seeds, and 15 to 20% skin and core. It has a mild, subacid flavor; some cultivars have apple-like flavor.[26] Church and Sorber[5] found that green (unripe) loquat fruit contained 10% less edible portion, 6% less total sugars, and lower percentages of total and soluble solids than did the fully mature fruit. The green fruit was higher in seed content, moisture, insoluble solids, acid, protein, alcohol-insoluble matter, pectic acid, and total soluble and insoluble ashes. The acidity decreased and the sweetness (sugars) increased, as the fruit matured.

Randhawa and Singh[26] reported that the principal constituents of ripe loquats were fructose, sucrose, and malic acid. The citric, tartaric, and succinic acids were also present. The glucose, maltose, and sucrose content of the fruit increased with maturity, although the maltose content disappeared with ripening.[12] Malic acid represented about 83% of the total

acids present, the remainder of the acid being citric acid. The malic and citric acid levels increased with maturity and then decreased, with citric acid decreasing at a faster rate than the malic acid. Rajput and Singh[19] noted almost no variation in acid values. There was a relatively high percentage of reducing sugars (5.10 to 7.70%) in 9 cultivars of loquat studied. The sugar:acid ratios varied according to the acid content. Hall et al.[7] reported that loquat pulp contained 0.42% crude protein, and 146 and 387 mg of essential and total amino acids, respectively, per 100 g flesh pulp. The leucine was found to be the most abundant, with cysteine-cystine as the least abundant amino acids. Among the non-essential amino acids, glutamic and aspartic amino acids were the most abundant with an unusually high level of proline.

While Rajput and Singh[19] reported that the ascorbic acid content of loquat varied from 2.5 to 4.1 mg/100 g pulp, Kumar[11] found that "Pale Yellow" and "Thames Pride" cultivars of loquat had 0.32 and 0.38 mg of ascorbic acid per 100 g pulp, respectively. Sadana[20] observed that the beta-carotene content of loquat pulp was 33.7 mg/g, equivalent to about 5600 I.U. of vitamin A. This amount is slightly more than 100% of the U.S. recommended daily allowance of vitamin A.[21]

The loquat has a relatively high proportion of potassium (about 210 mg/100 g pulp) and low sodium content (less than 1 mg/100 g pulp). This desirable mineral constitution of loquat, which is similar to that of orange juice, is recommended as a palatable therapeutic source of potassium for patients treated with diuretics.[3] Loquat also contains substantial amounts of calcium and magnesium. Other minerals present in small quantities are iron, zinc, and phosphorus.[21]

The loquat seeds, representing about 25% of the total weight of the fruit, contain 81.0% moisture, 2.6% total nitrogen, 5.4% soluble carbohydrates, 4.6% pentosan, and 4.3% crude fiber. The reducing sugars are present to the extent of 5.4% of the total carbohydrates.[9]

C. Postharvest Losses

Wither tip (*Colletotrichum gloeospoirioides*), collar rot (*Sclerotium* sp. and *Diplodia* sp.), twig blight and canker (*Cytospora chrysosperma*), and dieback caused by the important diseases affecting loquat.[17]

D. Loss Reduction Biotechnology

1. Harvesting, Handling, and Maturity

For fresh consumption, fully matured loquat fruits are harvested, although for jellies and cooking, slightly unripe (green) loquats are preferred. The fruits are commonly clipped by hand, and then sorted into two or three grades. The poorest grades are used for processing into jam, jelly, and other products. Randhawa and Singh[26] recommended careful packaging of loquats with soft packaging material during shipping to avoid bruisings.

2. Low-Temperature Storage/Packaging

Ogata[16] stored fully ripe and firm-ripe (mature) loquat fruits at 7° to 10°C and at 23° to 25°C. After 11 days of storage, he found that 65% of fully ripe fruit stored at the lower temperature were spoiled. The corresponding spoilage for the immature fruits was 40% and 0%, respectively. After storage at low temperature, mature fruit could be held for 3.5 days in ambient conditions. The total sugars, reducing sugars, nonreducing sugars, and total acidity decreased gradually during storage at 23° to 25°C in fully ripe loquat fruits.

Mukerjee[15] noted that loquat fruits picked at the climacteric stage could be stored in unsealed polyethylene bags at 3° to 5°C for about 8 weeks, and fully ripe fruit could be held at 3°C for 4 weeks without any deterioration. The low temperature storage prevented the characteristic browning of the fruit. Guelfat-Reich[6] stored fruits of four loquat cultivars, i.e., "Acco 13", "Tsrifine 8", "Acco 1", and "Tanaka", with and without polyethylene

wraps at 0°, 6°, and 8°C and 90% relative humidity for 4 weeks, and then at 20°C for 4 days. Storage at 0°C caused the least loss of weight, withering, and internal browning. Guelfat-Reich recommended a temperature of 0°C to store loquats for periods up to 3 weeks. The polyethylene wraps increased internal browning and postharvest rotting, even though they preserved the fresh appearance of the fruits and decreased weight loss. The wrapped fruit had poorer flavor and quality than the unwrapped fruit except for storage at 0°C. The storage behavior of the cultivars differed significantly. Singh[23] stored loquat fruits of two stages of ripening under three sets of conditions: in wheat straw in cardboard boxes, in perforated sealed polyethylene bags, and under normal conditions. Singh noted that a considerable water loss occurred in the fruit stored in wheat straw. The polyethylene bags also appeared to cause adverse chemical changes even though the water loss was retarded.

3. Processing

Loquats are largely consumed as dessert fruit; only a small quantity are processed into jams, jellies, and pies.[21] A significant quantity of the fruit is canned in Japan. Adam[1] studied changes in the pH of canned loquats in 100°C produced over a period of several years. The pH range of 4.0 to 5.4 was too high to prevent microbial growth during storage of the product, and a pH more than 4.0 was considered unsafe. Adam recommended reduction in the pH of the final canned product to increase storage stability.

II. MANGOSTEEN AND DURIAN

A. Introduction

The mangosteen *(Garcinia mangostana* L.) and durian *(Durio zibethinus* Murray) are delicious tropical fruits belonging to the family *Guttiferae* and *Bombacaceae,* respectively. They are well known throughout Southeast Asia and are grown widely in Malaysia, Indonesia, and the Philippines. The Mangosteen is a small-sized fruit, brown to purple in color when ripe and liked universally. It is covered with a thick parchment-like cortex, which is bitter due to its contents of tannins and xanthones. Inside the cortex are 4 to 7 pearly-white segments, similar to those of a citrus fruit but without a limiting membrane. These are soft, sweet, and have an excellent characteristic aroma. The pulp of the mangosteen is not filling, and it is juicy like that of a watermelon. The durian is a large heavy fruit covered with hard, hexagonal spines. It turns from green to yellow when ripe and can be broken into 5 locules by pressing it with hand. Each locule has 2 to 3 seeds which are surrounded by a soft aril, the edible part varying in color from white to cream, grayish yellow or pinkish, in some cultivars. The best cultivars are those which have small seeds and large arils. Seedless varieties are also known.[13]

B. Physiology and Biochemistry

The mangosteen fruit has a high percentage of soluble carbohydrates (18.6%) as sugars. It has a high moisture content (about 80%) as compared to the durian (about 60%) and is rather low in minerals and vitamins (Table 1). In contrast to the mangosteen, the durian has almost double the content of total carbohydrates (36.1%) and therefore tastes very sweet. About 1/3 of the carbohydrates present in the durian occurs as starch and at least 1/3 as sugars.[25] It is fairly high in its content of iron and is a good source of B vitamins and a fair source of ascorbic acid (Table 1).

C. Postharvest Losses

No serious postharvest diseases and pests of the mangosteen and durian have been reported, but a physiological disease called "gamboge" has been reported to affect the mangosteen.[8]

Table 1
NUTRITIONAL COMPOSITION OF EDIBLE PORTION OF MANGOSTEEN AND DURIAN FRUITS[1]

Component	Mangosteen	Durian
Moisture[a]	79.7	59.9
Calories	76.0	147.0
Protein[a]	0.7	2.0
Fat[a]	0.8	1.2
Total carbohydrates[a]	18.6	36.1
Fiber[a]	1.3	1.9
Ash[a]	0.2	0.8
Ca[b]	18.0	18.0
P[b]	11.0	56.0
Fe[b]	0.3	1.1
Vitamin A (I.U.)	0.0	Trace
Thiamin[b]	0.06	0.32
Riboflavin[b]	0.01	0.28
Niacin[b]	0.04	1.1
Ascorbic acid[b]	2.0	44.0

[a] Percent.
[b] mg percent.

From Anon., *Food Composition Table*, Food and Nutrition Centre, Manila, Philippines, 1968. With permission.

D. Loss Reduction Biotechnology

1. Low-Temperature Storage

Martin[13] stated that the mangosteen can be stored for 2 to 3 weeks at room temperature, and the shelf life can be increased for about a month by storing them at 9° to 12°C. Srivastava et al.[24] found that the optimum storage conditions for the mangosteen were 4° to 6°C with 85 to 90% relative humidity to obtain a maximum shelf life of 49 days. The soluble solids, total acidity, and ascorbic acid content of the fruit decreased, and reducing sugars increased during storage. The hardness of the fruit also increased, particularly at storage temperature of less than 4°C. The aroma and flavor were quite stable during the low temperature storage. Siddappa and Bhatia[22] reported that the shelf life of mangosteen, which was about 1 week at the room temperature could be extended for up to 6 to 7 weeks at 1.7° to 5.0°C.

The durian can be stored for about 30 to 35 days at 4° to 5°C and 85 to 90% RH.[14]

2. Processing and Utilization

A preserve called "manggis" is made from mangosteen fruit; it is delightful but does not capture the flavor of the fresh fruit. The fruit can also be processed into stable products such as juice, jelly, squash, and canned fruit segments; although much of the fruit aroma is lost during processing.[22] Martin[13] stated that freeze-drying of mangosteen may be advantageous.

The best durian fruits are consumed fresh. Its pulp can be added to ice-cream and can be made into jam. It can also be preserved with sugar, fried, or baked lightly. A paste made of prawns is often added to the preserves. The durian pulp can also be preserved by fermentation, a practice followed commonly in southeast Asia.[13] A delicious drink is made of milk and pulp in Malaysia.[4] The pulp of the durian can also be drum-dried and utilized in several ways.

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Chapter 18

JACKFRUIT AND BREADFRUIT, AMLA, PHALSA, JAMUN, BAEL AND WOOD APPLE, AND MULBERRY

I. JACKFRUIT AND BREADFRUIT

A. Introduction

The jackfruit and breadfruit belong to the genus *Artocarpus* of the family *Moraceae*, which also includes fig and mulberry. Jackfruit earlier was considered as *A. integrifolia* or *A. integra*. Sturrock[19] stated that *A. integra* properly refers to another species, while the species name for jackfruit is *A. heterophylla*. Chatterjee and Randhava[5] called it *A. heterophyllus*. Several other members of *Artocarpus* are of importance, including the breadfruit *A. altilis (Communis incisa)*. The latter is more tropical in its requirement than the jackfruit. Jackfruit probably originated in the Western "Ghats" of India.[7] The breadfruit is not grown widely in India, but it is an important staple food crop of Polynesia. Both fruits flourish on the sea coast, but they can also be grown on the humid hill slopes up to a height of about 1000 m and even in the drier parts when planted under a shelter of thick vegetation and well supplied with water.[11] Other fruits belonging to genus *Artocarpus* are monkey jack, *(A. lakoocha)* and Johere jackfruit *(A. champedon)*.

The jackfruit is a large-sized fruit weighing as much as 50 kg occasionally. Spikes of flowers are borne on footstalks which are short, deciduous branches arising on the trunk and the primary and secondary branches. Pollination is almost entirely by means of wind.[15] Hand pollination, however, increases the number of flowers fecunded and the weight of the fruit. The jackfruits are also borne at the base of the trunk, below the surface of the soil, giving rise to a common belief that they are also borne on the roots.

B. Postharvest Losses

The pink disease caused by *Botryobasidium salmonicolor* (Berk. and Br.) Venkatanarayan, affects both jackfruit and breadfruit. Fruit rot incited by *Phytophthora palmivora* also affects both fruits developing soft rots. The infection primarily takes place through whole or wounded skin in rough-skinned cultivars and through wounds in smooth-skinned cultivars. Water-soaked lesions may appear 48 to 78 hr after inoculation by the pathogen. The lesions enlarge to form light-brown spots with sporulating hyphae near the edge. *Rhizopus* rot of jackfruit caused by *R. artocarpi* Racib has been reported from Assam in India. The organism attacks the male inflorescence and young fruits. *Batocera rufomaculata* and larvae of the moth *Perina nuda* have also been reported to infest jackfruit.

C. Loss Reduction Biotechnology

1. Harvesting

In North India, the jackfruit blossoms in the winter and matures in the summer, but in more tropical regions cropping continues throughout the year,[7] producing a heavy crop annually.

2. Utilization and Processing

The sweet, ripe jackfruit is eaten as a dessert fruit; the unripe fruit may be consumed after cooking. The seeds are also cooked and eaten. In Java, the inflorescences and young fruits are also valuable food materials. The mature jackfruit may be stored at 11.1 to 13.3°C for about 3 to 6 weeks.[18] Slices of jackfruit are preserved in 50% sugar syrup with 0.5% citric acid. In a frozen state, they can keep for up to one year.

While the jackfruit has not been preserved to a great extent, the fruit can be processed into several durable products. Siddappa[16] reported that jackfruit "bulbs" could be preserved successfully by canning them in syrup. The edible bulbs constituted about 25 to 30% of the whole fruit. The rind portion which contained about 8% sugars, and the undeveloped bulbs excluding the gummy core, were processed into a jelly of good consistency, taste, and aroma. A little citric acid must be added to the water in which the rind is boiled, and more may be added later. A palatable beverage concentrate can be made from 10 lb of jackfruit pulp, 22.5 lb of sugar, 7.5 lb of citric acid, and 15 lb of water.[1] After cooking, the mixture is mashed and strained, and may be preserved by adding an ounce of potassium metabisulfite per 100 lb of the mixture.

II. AMLA

A. Introduction

The amla *(Phyllanthus emblica* or *Emblic officinalis)*, commonly known as emblica or Indian gooseberry, grows wildly in India. It belongs to the family *Euphorbiaceae,* to which also belongs another species, *Phyllanthus acidus (distichus),* commonly known as "otaheite gooseberry" or "star gooseberry".[7] In both these species leaves are small and arranged in two rows along small branches, some of which are deciduous. Amla fruits are also borne on the branches. The plant thus appears to bear flowers on its leaves giving rise to the name of the genus *Phyllanthus* which literally means "leaf flower". A third species of the genus; i.e., *P. fischeri* found in the forests of South India, also bears fruits suitable for human consumption.[11]

B. Physiology and Biochemistry

Like acerola, amla is one of the richest natural sources of ascorbic acid, containing as high as 747 mg/100 g pulp.[8] The amla contains about 5.0% tannins, which are thought useful to protect the ascorbic acid content of the fruit from oxidation.

C. Postharvest Losses

Pathak[12] described the rust incited by *Ravenelia emblicae* Syd. as a serious disease of amla in Rajastan (India). The leaflets show conspicuous rust pustules. Black spots appear on the fruits, occasionally covering the entire surface of the fruit. The affected fruit may drop before maturity. Plants with a severe attack on fruits show no symptoms on the leaves and vice versa. The occurrence of blue mold caused by *Penicillium islandicum* Sopp. has been reported from Varanashi (India). The disease is characterized by brown patches and water-soaked areas on the fruit. These distinct color zones (bright yellow, purple brown, and bluish green) are seen as the rot progresses. There is exudation of drops of yellowish liquid on the fruit, and the fruits emit a bad odor. The whole fruit finally gives a bluish green, pustuled, or beaded appearance.[12]

D. Loss Reduction Biotechnology

A substantial quantity of the ascorbic acid of the amla may be lost in the ordinary method of pickling, but much of it can be retained by boiling the fruit in water for a few minutes, and then putting it in a heavy salt solution. A durable powder may be made by mincing the fresh fruit and powdering it after drying naturally in the sun. The product contains about 10 to 16 mg of ascorbic acid per g of powder, which may be increased by refinement of the process. Jain and Lal[8] extracted about 90% of the ascorbic acid after steaming the amla fruits for 15 min at 15 lb pressure. According to these investigators amla extract can be used to fortify other products, although it gives a slightly astringent and bitter taste. Steeping the fruit for a week in 2% brine removes most of the astringency and almost a third of the

ascorbic acid. The extract can be preserved with potassium metabisulfite or by adding 7.5 lb of sugar to 8.5 lb of the extract.[7]

III. PHALSA

A. Introduction

Phalsa *(Grewia asiatica* L.) belongs to the family *Tiliaceae*, to which also belongs another species, *Grewia sapida* producing edible fruits. Phalsa is probably native of India.[7] Although phalsa is a popular delicious fruit, it is not likely to be cultivated on a commercial scale, since the fruit is highly perishable, needing immediate processing. It is presently grown for local markets. There is a need for development of bottling of phalsa juice and syrup to boost its production around cities. Phalsa is deciduous but loses its leaves slowly in the regions of mild winters. The plant begins to bear a year or two after planting, and the fruit ripens in the hot weather. The fruits are small and ripen gradually.

B. Postharvest Losses

Cercospora leaf spot *(C. grewiae)* and other fungal diseases caused by *Dasturella grewiae* and *Phyllosticta grewiae* have been found to cause heavy losses of phalsa. Rust of phalsa has been reported to occur in Hyderabad.[12]

C. Loss Reduction Biotechnology

Since the phalsa fruits ripen slowly and steadily, on one particular plant only a few fruits are ready to harvest on any one day. Several pickings are therefore required, increasing the cost of harvesting. The fruit, being highly perishable, must be sold within 24 hr of picking.

The phalsa is principally used to make a very delicious, refreshing drink. Khan[9] first extracted the juice in cold, then added water to the pomace, and extracted again after heating to 71.1°C. The two extractions were mixed, sugar was added (half the weight of pulp), and the squash was bottled and pasteurized at 79.4 to 82.2°C for 30 min. This product can alternatively be preserved by adding 0.1% sodium benzoate before bottling. The fruit may be crushed and strained for home use.

IV. JAMUN

A. Introduction

Jamun, Jaman, or Jambolan *(Syzyqium cumini)* belongs to the *Myrtle* family, a large family containing many members of horticultural interest, including guava. Jamun is one of the important fruits of India. It probably originated in India or the East Indies and occurs wild, as well as along the roads and in home gardens throughout the country. The fruit is a small purplish red in color and liked by many for its sweet astringent taste. There are a few types with superior, high quality, large-sized fruits with purplish flesh. They contain more pectin and make a good mild jelly.[10]

B. Postharvest Losses

Glomerella cingulata has been reported to be an important fungus inciting leaf spot and fruit rot. The affected fruits show small, water-soaked, circular, and depressed lesions which turn dark later. Concentric rings may appear on the infected portion, and the fruiting bodies of the pathogen may be arranged in the form of rings. Creamy spore masses develop on the fruiting bodies under humid conditions. The affected fruits eventually rot and shrivel completely.[12]

C. Loss Reduction Biotechnology

The jamun fruits are mostly consumed fresh. However, the fruit can be processed into juice, squash, jam, and jelly. Jamun juice makes a very delicious drink which is claimed to have medicinal value. The possibility of utilizing jamun seeds as a cattle feed has been investigated.[3] The seed is a rich source of calcium, a fair source of protein and carbohydrate, but poor in phosphorus.

V. BAEL AND WOOD APPLE

A. Introduction

The bael and wood apple have much in common, although both belong to different genera of the family *Rutaceae*. The bael is *Aegle marmelos*, while the wood apple is *Limonia acidissima*. Both trees grow wild in India and are considered indigenous. They have fruits with very hard rinds. The bael is a somewhat larger fruit than wood apple. Both fruit trees grow on poor soil, thrive in adverse climatic conditions and tolerate salinity and low temperatures.

B. Physiology and Biochemistry

The pulp of the wood apple is not of an attractive consistency but is eaten by many. It is regarded to have some medicinal value and is used to prevent and treat dysentry. The wood apple contains about as much ascorbic acid as the sweet orange.[7]

C. Postharvest Losses

The bael and wood apple have not been studied extensively with regard to their pests and diseases. Patel et al.[13] reported that the bael fruits are attacked by *Xanthomonas bilvae*, which is also capable of infecting the sour lime and the wood apple.

D. Loss Reduction Biotechnology

A very stiff jelly of attractive color can be made from the wood apple, although its flavor is somewhat harsh. It is more frequently mixed with jellies of other fruits such as guava to make blended jellies. Bhat[3] reported that a jelly having an exceedingly appreciable flavor and texture can be made from the wood apple. The fruit can also be converted into syrup, a very delicious chutney, and other processed products.

VI. MULBERRY

A. Introduction

Mulberry belongs to the genus *Morus*, of the family *Moraceae*, which is some times included in the family *Urticaceae*. The mulberry was formerly called *M. indica*, but it is now considered as a part of *M. alba*, the white-fruited species. *Morus alba* is used for silkworms in Europe and Asia, and it is indigenous to China. The fruit of *M. alba* is also used, but the most important species for fruit is the black mulberry, *M. nigra*, which is less hardy to cold. The mulberry is primarily a temperate plant rather than tropical or subtropical; some species, however, can grow well in the warmer climates. The mulberry is grown over a large part of India, but its cultivation is very small for the purpose of fruit.[7]

B. Postharvest Losses

Powdery mildew caused by *Phyllactinia corylea* (Pers. Karst.) and mosaic transmitted by *Rhopalosiphum maidis* (Fitch.) and *Mysuspersicae* have been reported to affect the mulberry.[13] Yellow-net-vein viral disease, characterized by chlorotic areas commencing from the margins of the affected leaves has also been observed.

C. Loss Reduction Biotechnology

The mulberry fruit is eaten fresh or stewed or made into juice. In Europe it is used for wine making. The fruit contains about 9% sugars and 0.95% acidity. Singh[17] reported that an attractive jam can be prepared from mulberry fruit by adding 3 lb of sugar and a small quantity of citric acid to 5 lb of fruit.

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Chapter 19

CUSTARD APPLE AND JUJUBE

I. CUSTARD APPLE

A. Introduction

The custard apple *Annona squamosa (Sharifa* or *Sitaphal)* belongs to the genus *Annona* of the family *Annonaceae*. The genus *Annona* contains more than 50 species. The custard apple is native to tropical America and was introduced in India by the Portuguese. It is now widely distributed throughout the tropical world and warmer subtropics. It has, however, not succeeded in most Mediterranean countries nor in California where winters are too cool for it. The custard apple is of commercial importance to Egypt, Central Africa, and Southern Asia. It is very successfully grown in Israel.[3]

Bullock's Heart (or Ramphal) is *Annona reticulata,* also known as custard apple or sweetsop. One of the best of the *Annonas* is the ''ilama'' *(A. diversifolia)*, which is an important fruit crop of Mexico and Central America.

B. Postharvest Losses

The Glomerella fruit rot of nuna *(Annona reticulata* L.) has been reported from Assam. The causal agent is *Glomerella cingulata*. Pathak[6] stated that infection begins at the blossom end in the form of a dry, blackish-brown spot which slowly spreads in all directions covering the entire fruit, which may cling to the tree or fall down.

C. Loss Reduction Biotechnology

1. Harvesting, Handling, and Maturity

The fruits are harvested while they are still firm, after the skin between the segments has turned a creamy yellow and may have begun to crack. If the fruit is left on the tree, the fruits split open and decay rather than becoming soft and ready to eat. Frequent pickings, every alternate day or so, are required to harvest the well-matured fruit. The picked fruits are usually kept in straw for a couple of days until they become soft. The fruit is very delicate in its ''ready-to-eat'' state and must be handled with utmost care. Because of this, the fruit must reach the consumer within a few days of picking. Transport to distant markets is, therefore, difficult. Prematurely harvested fruit has poor quality. In India custard apples are marketed locally without any packaging.[3]

2. Low-Temperature Storage

Cold storage does not offer promise in extending the shelf life of custard apples. The hard, immature fruits get chilling injury at 15.6°C or below.[2] The ripe fruits can be held for about 5 to 6 weeks at 4.4°C with the pulp portion of the fruit in good edible condition; however, the skin becomes brown and unattractive.

3. Processing

The custard apple is almost entirely consumed as a dessert fruit, although its pulp may be mixed with milk to form a delicious drink, or it may be made into ice-cream. The pulp has a pleasant texture and flavor. It is sweet with moderate acidity. The sugar content of the fruit compares well with that of the fig. Naidu and Saletore[5] reported that an oil suitable for soap making can be extracted, leaving the cake for use as a manure.

Hayes[3] mentioned other *Annonas* of importance: Soursop *(A. muricata)* can be eaten fresh or mixed with ice-cream or milk to form a famous drink, as is used in Cuba, Java and parts

of America. Cherimoya (*A. cherimola*) has unique flavor and high quality. Bullock's heart (*A. reticulata*) has fewer seeds, but its pulp is less delicately flavored as compared to that of custard apple.

II. JUJUBE (BER)

A. Introduction

The jujube or ber is one of the most common wild fruit trees of India. The jujube (*Zizyphas jujuba*) belongs to the family *Rhamnaceae*. According to Hayes[5] the Indian jujube differs from the Chinese in many ways, but despite these differences most Indian authorities refer it as *Z. jujuba*. Foreign authors have generally classified the Indian jujube as *Z. mauritiana*. There seems to be little difference between the two species. Jujube is indigenous to the area stretching from India to southwestern China and Malaya. Synonyms for *Z. jujuba* are *Z. vulgaris* and *Z. sativa*.

B. Postharvest Losses

The powdery mildew of *Zizyphus* sp. caused by *Odium erysiphoides* Fr. is widely distributed in India. This disease is so severe that an entire crop may be wiped out: It causes a brown discoloration and shedding of young fruits. It usually occurs from November to April. The fungal mycelium appears to overwinter in new shoots arising annually during February.[6] The fruit fly is a serious pest of the jujube in India.

C. Loss Reduction Biotechnology

1. Utilization

In India almost the entire crop is eaten fresh. The sugar content of the Indian jujube varied from 12 to 18.7%.[8] The ascorbic acid varied from 50 to 67 mg/100 g of pulp. Another report by Riaz-ur-rahman et al.[7] stated that the ascorbic acid content of jujube in Punjab varied from 45.2 to 150.3 mg/100 g. The vitamin C content of the fruit is lost very rapidly in storage, especially at the higher temperatures. The Chinese species contain higher sugar and ascorbic acid contents.

2. Chemical Control of Losses

A satisfactory control of the powdery mildew of the jujube can be achieved by the application of sulfur dust. The disease can also be controlled effectively by spraying with karathan (15 g/100 ℓ of water). The best results are obtained with benomyl (Benlate®) followed by afugan spray (both 0.07%).[6]

3. Processing

Candied jujube are an excellent product with great demand in the Punjab.[1] In Burma the fruits are dried and made into jam, or powdered and mixed with jaggery before consumption. Delicious drinks are made from the powdered fruit. Morton and Morton[4] reported that an excellent jelly could be made from the unripe fruits of the Indian jujube. Reed[9] stated that a jelly of good consistency can be made by adding a proper amount of pectin and acid to this fruit, or by mixing it with other fruits. This method retains a fairly large amount of ascorbic acid.

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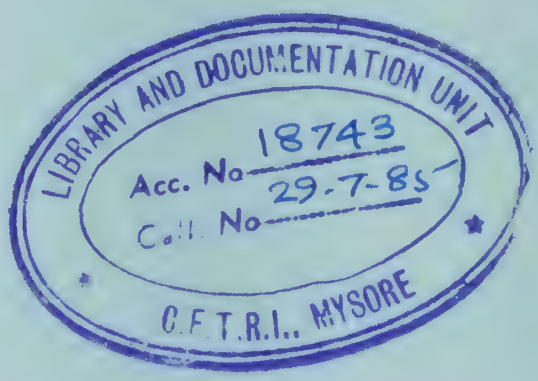

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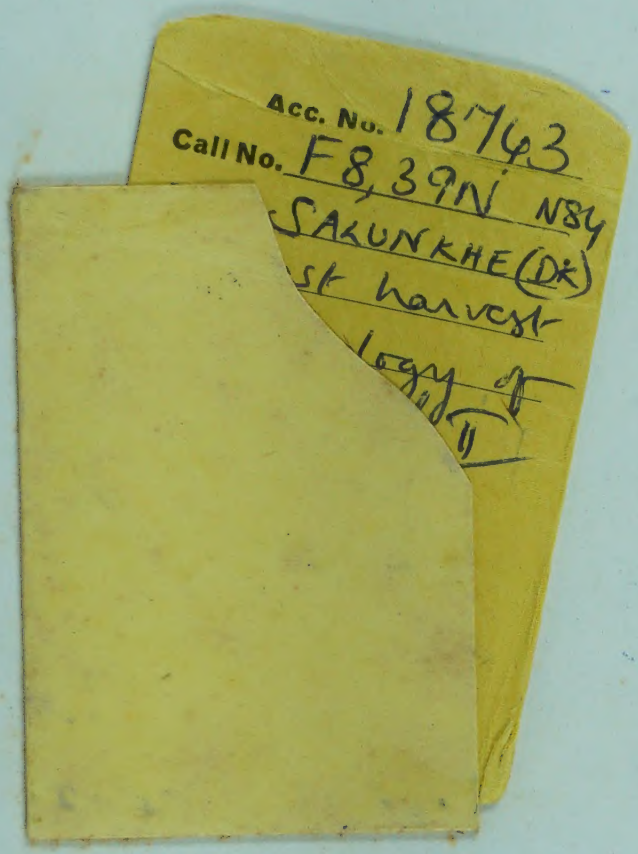
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